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Report summarizes scientific understanding of the extent and causes of pesticide contamination of ground water and its potential health significance. The document includes discussions of chemical-physical properties of pesticides, and natural and man-made site conditions conducive to leaching. The report also summarizes statutory and program authorities available to address the problem pesticide pollution, and the various Federal, State and local agencies who may be involved. The report is the findings of an EPA-wide, multi-disciplinary task force.

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This report presents the findings of EPA's Working Group on Pesticides in Ground Water, established in 1985 to develop background materials and identify issues and options for development of a strategy to address pesticides in ground water. With the work of this group as foundation, strategy development has now been broadened into a major Agency strategic initiative on agricultural chemicals in ground water, including both pesticides and fertilizers.

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INTRODUCTION

For many years, our society has enjoyed the benefits of using pesticides to control weed and insect pests. An assumption behind much of this use has been that pesticides will either degrade quickly or bind to soil particles until they eventually break down into more innocuous substances. Only within the last decade have scientists learned that pesticides applied to the land can leach through layers of the earth's surface to enter the ground water below. Leaks and spills, as well as disposal practices, can also result in pesticide contamination of ground water.

Increasing national awareness of the need to protect our ground water resources has led to a recognition that widespread distribution and use of pesticides is a potentially significant source of ground-water contamination. Efforts are being initiated at all levels of government to understand the nature of this problem and devise appropriate solutions.

The U.S. Environmental Protection Agency (EPA) has responsibility under a variety of statutes to protect the quality of the nation's ground water as well as direct responsibility for regulating the availability and use of pesticide products. Since the early 1970's, EPA's Office of Pesticide Programs has been evaluating the leaching potential of new and existing chemicals and has taken regulatory actions, including cancellation, on several chemicals found to have the potential to contaminate ground water. During this period, EPA has also undertaken monitoring studies and research efforts designed to help characterize the risks pesticides pose to ground water.

Shortly after EPA's Ground-Water Protection Strategy was issued in August, 1984, the Agency initiated an intensive review of existing information and scientific knowledge about the extent of pesticide contamination, its causes, its potential health impacts, and the statutory authorities and programs available to help address the problem. This report presents the findings of the Agencywide review. It is intended as a background document to help inform Federal and State policy makers and the interested public as they grapple with the complexities of the pesticides in ground water problem. This report will also provide background for the Agency's Agricultural Chemicals in Ground-Water Strategy now under development and soon to be released for public comment.

CHAPTER ONE

THE PESTICIDES IN GROUND WATER CHALLENGE

I. The Ground Water Resource

Ground water is a vast resource beneath the surface of the earth. It occurs in aquifers, which are geological formations that contain enough water to yield usable amounts to wells and springs. The volume of known ground water in the United States is about 50 times greater than the total volume of surface water.

In 1980, about one-fourth of all the fresh water used in the United States came from ground water. This was a 162 percent increase in ground water use over 1950; the percentage continues to increase. The principal uses are for irrigation and public drinking water. While smaller amounts are used in industries and rural households, the degree of dependence on ground water for industrial and rural household use is often higher. Clearly, ground water is critical to millions of Americans.

The likelihood of pesticide contamination of ground water and its impact on the environment depend in part on geologic and hydrologic characteristics that vary from location to location. These characteristics determine how quickly ground water moves, how and whether it is discharged to surface water, how deep it is below the surface layer, how withdrawing it affects surface water, how effectively soils filter out pesticides, and how easily pesticides can enter aquifers. This complex combination of factors makes it difficult to predict what level or duration of ground-water contamination a pesticide may cause at different sites. Because of this uncertainty, discovery of relatively localized pesticide contamination of groundwater may be viewed as an indicator of probable, more widespread contamination.

Movement of Ground Water

In strata containing unconsolidated sand and gravel, ground water moves as fast as 800 feet a year or more. Ground water may move even more rapidly through cavernous limestone formations. In general, however, ground water moves very slowly. Formations containing layers of consolidated clays with little fracturing allow ground water to move only a few inches a year. These slow rates, in most cases, prevent contaminants from spreading or mixing quickly, concentrating them in slow-moving plumes that may remain undetected until water wells or surface waters are contaminated. Plumes are typically present for many years -- sometimes decades or longer.

Discharge to Surface Water

Even though ground water moves slowly through the ground, it usually eventually discharges to surface waters. In some areas of the country, springs and aquifers contribute large quantitites of water to the flow of streams. In the coastal states, aquifers discharge into the seas and wetlands and supplement fresh-water flows. In other areas, ground waters discharge into lakes, ponds, and inland wetlands.

If ground water becomes contaminated, the contamination may eventually appear in surface water. Depending on the geologic and hydrologic characteristics of the aquifers involved, contaminated ground water may discharge to surface areas as quickly as within one day or take as long as a thousand years or more.

Characteristics of Recharge Areas and Unsaturated Zones

The potential for contamination also depends on the characteristics of recharge areas, that is, areas where water enters the aquifers through geologic formations. In many parts of the country, the recharge areas are close to the land surface and may be affected signficantly by land management practices such as pesticide application.

The depth and types of soils above the aquifer, the depth from the earth's surface to ground water, and many other factors affect the potential for contamination. In some areas, the water table is within 20 feet or less of the land surface, and the unsaturated zone (the layer between the surface and the water table) consists of highly permeable sand and gravel beds. Ground water in these areas may become contaminated relatively quickly by pesticides. In other areas, the unsaturated zones are deep, and their beds consist of layers of highly impermeable materials. Contaminants in such areas may not reach ground waters, or will do so only after a very long time. Finally, certain aquifers are buried deep beneath other aquifers. They become contaminated either through leakage from other aquifers, through poorly cased wells, or through pollutants entering their recharge zones.

II. Sources of Pesticide Contamination

Ground water may become contaminated by pesticides at any point in the life cycle of a pesticide: its manufacture, distribution in commerce, storage, use on the land or in industrial settings, and disposal. The sources can be grouped into two general categories based on the characteristics of the contamination which may occur and the type of actions that can be taken to prevent it.

The first category includes accidental spills and leaks of pesticides at manufacturing facilities and at other establishments where bulk pesticides are stored and handled, such as agricultural chemical dealerships and commercial applicator facilities. Also included in this category are places, including hazardous and municipal waste landfills and other waste handling or treatment facilities, where bulk pesticide wastes are disposed of. A variety of Federal and State environmental laws and regulations contain provisions to prevent contamination from these "point" sources. Should contamination occur, it can be characterized as concentrated plumes that are relatively localized and thus able to be at least partially cleaned up using the techniques typically available for other ground-water contamination. In addition, the parties who are responsible for the incident can often be identified and required to pay for the cleanup.

By far, pesticides are most commonly used to control insect and weed pests on agricultural and forest land as well as on homes and gardens and on highway and utility rights of way. When pesticides are applied to the land, they are carried above, over, and through the ground by rainfall, runoff, infiltration, and snowmelt. Pesticides dissolved in runoff water are carried to surface water or may enter ground water through a variety of potential routes (such as uncapped wells or sinkholes). Pesticides may also leach into ground water through infiltration at either the site of application or in runoff retention areas. Also associated with land application of pesticides is contamination from irrigation systems used to apply pesticides ("chemigation") which may siphon pesticides back into the ground-water well if not equipped with proper safety devices.

Contamination may also result from small but frequent spills at mixing and loading areas on the farm field, and from improper disposal of small quantities of leftover pesticides and their containers. Generally, contamination from land application extends over a wide area (a whole farm or farming region) at very low concentrations which may build up over the years of pesticide use. Contamination from leaching may also mix with contamination from chemigation or small spills at the same site, making it difficult to determine the precise cause of the problem.

At the present time, there are no techniques available for cleaning up contamination that involves a large geographical area, and it is virtually impossible to identify the party or parties who are responsible since pesticide use is a common practice. For these "nonpoint" or diffuse sources, prevention is the key. Prevention efforts will necessarily involve both regulation of individual pesticides as well as changes in pest control and land management practices. In most cases, when there is widespread low levels of contamination, the only effective means of providing clean water is to either treat the ground water before use or find an alternate supply.

The table on page 5 summarizes potential sources of contamination at each stage in the production/use cycle.

Table 1: Potential Sources of Pesticide Contamination of Ground Water

	Manufacturers/ Formulators	Dealer	Industrial User	Land Application
SPILLS AND LEAKS				
Storage Areas	X	X	X	X
Storage Tanks/ Pipelines	X	X	X	
Loading/Unloading	X	X	X	X
Transport Accidents	X	X	X	X
DISPOSAL				
Process Waste	X		X	
Off-specification material	X			
Cancelled products	X	X	X	X
Containers	X	X	X	X
Rinsate				X
LAND APPLICATION				
Leaching*				X
Backflow to irrigation well				X
Run-in to wells, sinkholes				X
Mixing/loading areas				X

*Leaching potential affected by chemical-physical properties of pesticide, hydrogeologic setting, and application and cultivation practices

III. Extent of Pesticide Contamination

At present, the extent of pesticide contamination of ground water cannot be determined. Numerous surveys have been undertaken for different reasons using different design strategies. These studies have provided information about a limited number of pesticides in specific areas, but they are small pieces of a very large and intricate puzzle.

Past monitoring for pesticides in ground water has been minimal. Before 1979, relatively little systematic water monitoring was focused on ground water. Surface water and urban drinking water supplies received almost all the attention. While a number of urban water systems draw on ground water, they have been required to routinely monitor for only six pesticides since 1975: endrin, lindane, methoxychlor, toxaphene, 2,4-D and 2,4,5-T. Of these pesticides, only lindane, methoxychlor, and 2,4-D are still being used to any appreciable extent; most or all uses of the others have been removed from the marketplace by EPA. Other ground-water monitoring efforts have focused on contaminants other than pesticides such as nitrates from fertilizers, or more recently, organic chemicals from hazardous waste disposal sites.

Testing of pesticides for their potential to leach through the soil and contaminate ground water has also been very limited. Most pesticides on the market today were registered for use before sophisticated environmental fate testing was routinely required.

Several major episodes of ground water contamination by pesticides brought the problem to national attention. Prior to 1979, there was a general belief that ground water was protected from pesticide contamination by chemical degradation processes in and on the soil and by impervious layers of subsoil, rock, and clay. The discovery of DBCP in numerous wells of California's Central Valley was the first big step in the dismantling of this long-held belief.

The first discoveries of DBCP in wells were traced to unlined holding ponds used for disposal by a company producing the pesticide. Initial reaction was that pesticide contamination of ground water would only be a problem when large amounts of these chemicals were placed on the soil as a result of hazard-of California and in several municipal drinking water systems drawing on ground water supplies. The source of contamination was the widespread and approved use of this chemical in agriculture. DBCP ground-water contamination was soon found in the States of Arizona, Hawaii, Maryland, and South Carolina.

In the same year that DBCP was discovered in California wells, another pesticide, aldicarb, was found in wells on Long Island, New York. The Long Island contamination was found to be a result of normal, approved use of this pesticide on potato fields to control insects and nematodes. In 1980, aldicarb was found in 81 wells in the Central Sands region of Wisconsin, again, as a result of the use of this pesticide on potato fields. Since then, aldicarb has been found in wells at levels of concern in eleven other States.

Perhaps the most serious case of pesticide contamination of ground water began with the discovery in 1982 of the pesticide ethylene dibromide (EDB) in two California wells and three wells in Georgia. By the end of the following year, EDB contamination of ground water had been discovered in 16 different counties in California, Florida, Georgia, and Hawaii. The EDB levels reported varied between 0.02 ppb and 300 ppb, but typically were found between 0.05 and 5 ppb. EDB has been described by the National Cancer Institute as "the most potent cancer-causing substance ever found in [their] animal test program." Finding EDB in numerous wells caused EPA to issue an immediate emergency suspension of all EDB use as a soil fumigant in September 1983.

The discovery of pesticide contamination has raised significant concern about the threat posed to the nation's ground water. However, these episodes do not provide a comprehensive picture of the problem. The design of monitoring efforts to date has not generally been intended to provide information on the general relationships between ground-water contamination and the varied physical/chemical properties of pesticides, the manner in which they are used (or perhaps, misused), and the environmental conditions that affect the persistence and movement of these chemicals in the soil. As a result, EPA's efforts to develop controls to mitigate ground-water contamination by pesticides has been hampered by a lack of basic information. EPA's current and planned efforts to gather extensive information on pesticides in ground water are described in detail in Chapter Three.

Table 1 is an EPA-compiled summary of pesticides found in ground water due to normal application to the land, in various States where monitoring has occurred. In 1984, a total of 12 ground water due to normal application to the land, in various States where monitoring has occurred. In 1984, a total of 12 pesticides were detected in ground water in 18 States. By 1985, 17 pesticides had been detected in 23 States. The Agency anticipates that additional monitoring will reveal more locations where pesticides have entered ground water.

As many as 50 other pesticides have been detected in ground water, but the sources of the contamination are uncertain and in some cases were the result of accidental spills or leaks rather than leaching from land application.

Table 2: Typical Positive Results of Pesticide Ground-Water Monitoring in the U.S.† as a Result of Normal Land Application

Pesticide	Use*	State(s)	Typical Positive, ppb
Alachlor	H	MD, IA, NE, PA	0.1-10
Aldicarb (sulfoxide & sulfone)	I, N	AR, AZ, CA, FL, MA, ME, NC, NJ, NY, OR, RI, TX, VA, WA, WI	1-50
Atrazine	H	PA, IA, NE, WI, MD	0.3-3
Bromacil	H	FL	300
Carbofuran	I, N	NY, WI, MD	1-50
Cyanazine	H	IA, PA	0.1-1.0
DBCP	N	AZ, CA, HI, MD, SC	0.02-20
DCPA (and acid products)	H	NY	50-700
1,2-Dichloropropane	N	CA, MD, NY, WA	1-50
Dinoseb	H	NY	1-5
Dyfonate	I	IA	0.1
EDB	N	CA, FL, GA, SC, WA, AZ, MA, CT	0.05-20
Metolachlor	H	IA, PA	0.1-0.4
Metribuzin	H	IA	1.0-4.3
Oxamyl	I, N	NY, RI	5-65
Simazine	H	CA, PA, MD	0.2-3.0
1,2,3 Trichloropropane	N (impority)	CA, HI	0.1-5.0

†Total of 17 different pesticides in a total of 23 different States.

*H = herbicide
I = insecticide
N = nematicide

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CHAPTER TWO

STATUTORY AUTHORITIES AND PROGRAMS

Just as the problem of pesticides in ground water is complex, so is the array of statutory authorities and programs that may be used directly or indirectly to prevent or mitigate contamination. This chapter describes the laws and programs EPA administers as well as programs of other Federal agencies and the States which provide the institutional framework for addressing the pesticides in ground water problems.

I. EPA Authorities and Programs

A. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

Pesticide Registration

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) gives EPA broad authority to register and reregister pesticide products, and otherwise regulate pesticide marketing and use in the U.S. In recognition of the fact that most pesticides afford our society important pest control benefits while also inherently posing a degree of hazard to nontarget species, the statute mandates a balancing of the risks and benefits associated with any pesticide use. Those uses that do not cause "unreasonable adverse effects" to man or the environment, taking into account both their risks and benefits, may be or may remain registered. Uses that pose unreasonable adverse effects may be denied registration or removed from the market after their initial registration. EPA may place restrictions on the use of pesticides that are registered to reduce the risk they present.

In addition to registering or placing restrictions on the use of individual pesticides, EPA has other mechanisms which may be employed to regulate or establish policy for all or a group of pesticides. These mechanisms include the rule-making process (including negotiated rulemaking), Pesticide Registration (PR) notices, and other special policy statements.

In evaluating a pesticide's risks, EPA takes into consideration both its inherent toxicity and the potential routes of human exposure to the compound. Since recent data indicates that people may be exposed to pesticide residues in ground water if it is used as drinking water, EPA is now considering this additional potential source of human exposure to pesticide residues. The Agency is using the full range of FIFRA authorities to gather and evaluate pertinent data and regulate pesticides that pose a risk to ground water, up to and including cancellation of products that pose an unreasonable risk due to their occurrence in ground water.

New Chemicals. EPA requires a full complement of data on human health and environmental effects for registration of a new pesticide today. Among the environmental fate data currently required are a variety of studies needed to evaluate the leaching potential of the pesticide. Monitoring studies may also be required. EPA's intent is to assure that any pesticides registered for the first time today or in the future will not pose an unreasonable risk to human health due to contamination of ground water.

Existing Chemicals. Many of the pesticides currently registered and on the market were first registered years ago, before EPA's current data requirements were developed or promulgated as regulations. The toxicity and environmental fate data bases for these old chemicals are often inadequate by today's standards. The initial decisions to register these pesticides are being reevaluated on the basis of updated data bases.

The pesticide registration and reregistration programs under FIFRA enable the Agency to screen both old and new chemicals carefully for potential unreasonable adverse effects, including any risks posed by the chemicals' ability to leach to ground water. Suspected leachers are subjected to further testing by their producers. Demonstrated leachers that pose hazards by virtue of their toxicity and use patterns may be the subjects of regulatory actions ranging from label direction changes and use restrictions to suspension and cancellation of product registrations.

While much of the chemical-specific data on pesticide leaching potential is being required of pesticide registrants, FIFRA research and monitoring authorities and the Agency's pesticide modeling capabilities enable EPA to produce data needed to predict, detect, and evaluate pesticide occurrences in ground water. FIFRA product classification and applicator certification and training authorities provide a useful vehicle for assuring proper use of pesticides that are actual or potential leachers, and for conveying information on prevention of ground-water contamination to pesticide users. FIFRA industry and user compliance programs implemented in cooperation with the States make the Agency's prevention decisions enforceable.

Applicator Certification and Training Program

The primary vehicle available to EPA for educating pesticide applicators in the safe and proper use of pesticides is the certification program authorized by the 1972 amendments to FIFRA. Pesticides that are highly toxic or that have serious environmental hazards associated with their use may be classified as "restricted use" pesticides. They may only be used by, or under the direct supervision of, applicators who have been certified as competent to use these pesticides.

Currently, all but two States conduct certification and training programs for both private and commercial applicators. (EPA operates Federal certification programs in the States which do not operate their own programs.) State certification programs must meet standards which were set by EPA through regulation. In general, State Cooperative Extension Services are responsible for providing training to pesticide applicators and State lead pesticide agencies are responsible for certifying the competency of applicators. EPA provides grant funds to the State lead agencies for administrative costs of maintaining the certification program; FY 86 funds are approximately $1.2 million. EPA also provides funds to the U.S. Department of Agriculture's Extension Service for allocation to State Extension agencies to provide the training to applicators; FY 86 funding to the Extension Service is approximately $1 million.

As a minimum requirement for certification, private applicators (e.g., farmers) must demonstrate their knowledge of pest problems and pest control practices; proper storage, use, handling, and disposal of pesticides and containers; and knowledge of other subject areas as specified by regulation. The extent and depth of training provided and the method for certifying the private applicator is determined by each State.

Commercial applicators, however, are required to demonstrate their competency by completing written examinations prior to certification. As specified by regulation, testing must cover general information on pest control and safe use of pesticides and more specific information relating to the category (e.g., agricultural pest control, forest pest control, etc.) under which the commercial applicator will be certified. Training generally precedes the completion of examinations.

An estimated 300,000 commercial and 1.24 million private applicators have already been certified. While many States require recertification at specified intervals, the requirements for recertification vary widely and do not necessarily include retraining.

Over the years, the number of pesticides classified as restricted has grown substantially, and precautions for personal safety and environmental protection have become more complex. A special task force was established in 1985 by the Assistant Administrator for Pesticides and Toxic Substances to examine the applicator certification and training program and make recommendations for changes that would enhance the program's effectiveness. In addition to recommendations covering a range of issues related to the operation and content of the program, the task force recommended inclusion of ground-water information. Development of national ground-water educational material is now underway.

FIFRA Compliance and Enforcement

Historically, primary responsibility for enforcing FIFRA rested with the Federal government. In 1972, Congress amended FIFRA to allow EPA to set up cooperative programs with the States to share the responsibilities for enforcing the Act and for training and certifying applicators. The 1978 amendments strengthened the State role, giving qualified States responsibility for enforcing the requirements governing pesticide use. All but two States (Nebraska, Wyoming) have assumed this responsibility.

Before the 1972 amendments, the Federal program was limited to enforcing such product-related violations as mislabeling, inefficacy, chemical deficiencies, and failure to register. Only criminal sanctions were available to address violations. The 1972 amendments authorized EPA to enforce the requirements governing pesticide use and provided for administrative civil penalties as well as criminal sanctions.

Pesticide users must comply with label directions specifying the crops and pests the product can be used on; approved rates and methods for application; and the precautions that must be taken before, during, and after application. Along with the shift in primary responsibility for use enforcement to the States, the focus of the program has shifted gradually away from emphasizing productrelated enforcement to paying greater attention to the health and environmental problems that arise from using pesticides.

Under FIFRA cooperative enforcement grants, each State sets priorities for annual compliance efforts by identifying and ranking specific pesticide use and product-related problems the State is experiencing. Each State must also evaluate whether certain national problems are problems the State needs to address. For the first time in FY 85, ground water was identified as a national problem for such consideration. Many States have ground water initiatives as part of their overall compliance programs.

In addition to directly administering compliance programs in Nebraska and Wyoming, EPA conducts national direct compliance monitoring programs. In cooperation with the Food and Drug Administration, EPA audits laboratories performing tests in support of pesticide registrations to ensure that the quality of the data submitted is satisfactory. The environmental fate data and monitoring studies now being required to help the Agency determine a pesticide's leaching potential are subject to such audits. EPA also inspects pesticide imports to ensure that they comply with FIFRA requirements.

B. EPA's Ground-Water Protection Strategy

EPA's Ground-Water Protection Strategy, issued in August 1984, sets forth the Agency's policy framework for ground-water protection in all programs, including pesticides. To foster implementation of the Strategy, EPA established a new Office of Ground-Water Protection in Headquarters and ground-water offices in each of the 10 EPA Regions.

Central to the strategy is a differential protection policy designed to ensure a level of protection that is appropriate to the use, value, and vulnerability of the ground water. The most stringent protection requirements apply in areas where the ground water is both highly vulnerable to contamination and either an irreplaceable source of drinking water or ecologically vital (Class I). The vast majority of the nation's ground water will be in Class II, where the water is a current or potential source of drinking water or has other beneficial uses (such as for irrigation). In these areas, "baseline" protection measures designed to reduce the risk of contamination apply. Ground water of little or no potential for future use because of natural or man-made contamination is defined as Class III. Here, some relaxation of baseline requirements might be allowed if the quality of the water is not harmful to human health or the environment.

To implement this policy, each EPA program that governs an activity affecting ground-water quality is devising management strategies to afford the appropriate level of protection to each class. These strategies may include such elements as siting criteria, engineering and performance standards, operating requirements, monitoring requirements, and best management practices.

A second major policy in the strategy acknowledges that States have primary responsibility for ground-water protection. EPA's role is to set national policy and standards and to provide the technical and other assistance needed by the States to improve State capacity to protect ground water. During FY 85 and FY 86, EPA provided $7 and $6.7 million, respectively, in Section 106 grants under the Clean Water Act to help the States develop and implement ground-water protection strategies.

All States are now in the process of developing and/or implementing strategies for ground-water protection. In addition to using the supplemental Section 106 grant funds to enhance interagency coordination on ground water issues generally -- including coordination with pesticide and agricultural agencies -- several States are using the funds for specific efforts to control pesticides in ground water. In FY 85, nine States used their grants to help assess the problem, develop monitoring strategies, and develop management alternatives for pesticides in ground water.

In addition to the State grant program, EPA has initiated several other actions to improve ground water protection efforts. The development of an Agricultural Chemicals in Ground Water Strategy represents a major step toward addressing a source of contamination which was identified in the EPA Ground-Water Protection Strategy as needing further attention. It also represents furtherance of another goal of the Strategy: to enhance coordination and cooperation between EPA programs which affect ground water.

A report on ground-water research prepared by a special EPA Science Advisory Panel includes recommendations for needed Agency research that can assist in addressing pesticide contamination problems. The Ground-Water Monitoring Strategy developed in 1985 includes actions to improve the quality, accessibility, and utility of all ground-water monitoring data, including data collected on pesticides.

C. Safe Drinking Water Act (SDWA)

The Safe Drinking Water Act (SDWA) is designed to assure that public water systems (serving over 25 persons or with 15 connections) provide water meeting minimum standards for the protection of public health. As required by the Act, EPA publishes drinking water regulations for contaminants which may have adverse effects on the health of persons. These regulations specify either (1) "maximum contaminant levels" (MCLs) which specify the maximum contamination level of chemicals which may be present in the water served to the public, or (2) treatment techniques that must be used to remove contaminants which are either technically or economically infeasible to detect. Its authorities do not extend to private wells.

EPA is required to establish "recommended maximum contaminant levels" (RMCLs) before establishing MCLs. RMCLs are nonenforceable health goals which are set at a level at which, in the Administrator's judgement, "no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety." The maximum contaminant levels (MCLs) must be set as close to RMCLs as is feasible. Under the SDWA, feasible means "with the use of the best technology, treatment techniques, and other means, which the Administrator finds are generally available (taking costs into consideration)."

MCLs are enforceable, and EPA requires public systems to monitor and report findings to assure that the water they provide complies with the MCLs. EPA proposed RMCLs for about a dozen pesticides in November 1985. Final RMCLs and proposed MCLs for these pesticides are scheduled to be issued in the Spring of 1987.

EPA's Office of Drinking Water also sets non-regulatory health advisories which provide information on health effects, analytical methodology, and treatment technology on contaminants not covered by drinking water regulations and on short-term exposure to contaminants covered by drinking water regulations. Health advisories describe concentrations of contaminants in drinking water at which adverse effects would not be anticipated to occur, with a margin of safety included to protect sensitive members of the population. Health advisories are not legally enforceable Federal standards, and are subject to change as new and better information becomes available. The advisories are offered as technical guidance to assist Federal, State, and local officials make decisions regarding use of water that has become contaminated. Health advisories for several pesticides have been issued, and the Agency plans to issue several dozen more by 1987.

If minimum Federal requirements are met, States may assume primary responsibility for enforcement of the national drinking water regulations. States are permitted to set standards that are more stringent than Federal standards and to set standards for substances not addressed by Federal regulations.

Under other SDWA provisions, EPA sets regulations to control underground injection (the UIC program). Agricultural drainage wells, classified as Class V wells, are not now subject to Federal regulation. They are a potential source of ground-water contamination if pesticide-laden surface runoff enters the drainage well. EPA also administers the sole source aquifer program authorized by the SDWA. States (as well as cities, companies, and individuals) may petition EPA to designate a sole source aquifer. Once designated, the States may petition EPA to review the potential of a Federally funded project to contaminate the aquifer.

D. Clean Water Act (CWA)

Nonpoint Source Program

The Clean Water Act (CWA) recognizes that achieving water quality goals will require controlling nonpoint sources of pollution. Concerted nationwide efforts to understand the nature of and solutions to nonpoint source pollution were first required in 1972 under Section 208 of the CWA. States and areawide agencies were called upon to develop and implement plans for managing water quality. Among the nonpoint pollutant sources listed were agriculture and silviclutures; pesticides used in these activities may contaminate both surface and ground water.

During the mid and late 1970's, EPA funded States to develop initial plans to assess both point and nonpoint source problems and control needs. While the principal focus was on surface water, some States also used Section 208 funds for development of ground-water management programs.

With elimination of funding under Section 208 after fiscal year 1981, States and local governments are increasingly using their own funds, supplemented by other CWA funding sources, to fund nonpoint source control efforts and related continuing water quality management efforts. Many States are updating their original plans and developing information useful for ground-water management programs.

Currently, EPA provides grant funds under Section 106 and Section 205 (j) of the CWA to support a full range of water quality management activities, including the development and implementation of nonpoint source and ground-water management programs. Nonpoint problems are also addressed through funding provided by the CWA Clean Lakes Program, Great Lakes Demonstration Projects, and Great Lakes and Estuarine Management Programs.

In general, EPA's nonpoint program focuses on providing guidance and information transfer between and among States and localities and in coordinating the nonpoint source-related activities of other Federal agencies. In addition, EPA provides financial assistance to States and other agencies under a variety of programs for nonpoint source monitoring/assessments, planning, program development, and demonstration projects.

National Nonpoint Source Policy. During 1984, EPA convened an interagency Nonpoint Source Task Force which led to the development of a National Nonpoint Source Policy and individual agency strategies to carry out the Policy. The Policy's objective is to accelerate the development and implementation of nonpoint source management programs for both surface and ground water. The Policy emphasizes that site-specific and source-specific decision making is the key to effective implementation.

The Policy defines the roles and responsibilities of the various levels of government and the private sector. States have the lead for implementing nonpoint source programs for State and private lands. Local, areawide, and interstate agencies are responsible for implementing programs in their jurisdictions in coordination with States. The Policy calls for Federal agencies to integrate nonpoint source concerns, as appropriate, into their existing programs and delivery systems. EPA, as required by the CWA, is to serve as the lead Federal agency in coordinating interagency and State nonpoint source management actions. And finally, the cooperation and efforts of the private sector are recognized as a key element.

Agricultural Nonpoint Source Controls. In agricultural areas, nonpoint source control efforts generally involve developing and implementing site-specific plans for reducing pollutants from individual farms. Under a variety of arrangements between Federal, State, and local agencies, the land owner receives technical and cost-sharing assistance to implement structural, vegetative, and management practices needed to reduce soil erosion, and increasingly in more recent years, to reduce pollution from use of pesticides and fertilizers. While most of these latter efforts have been designed to address surface water quality, an increasing number of local projects are now being refined to control pollutant loadings to ground water as well. A key feature of some of these efforts is tying the availability of cost-sharing assistance to participation in Integrated Pest Management programs.

National Pollutant Discharge Elimination System (NPDES)

Each facility which discharges effluent to the nation's waterways is required to obtain a permit specifying the amount of pollutants which may be released. In addition to the discharge permit itself, many facilities are also required to have plans for handling spills and leaks from materials handling. While the primary purposes of the National Pollutant Discharge Elimination System (NPDES) is to protect surface water quality, reduction in pollutant loadings to surface water also reduce the risk of ground-water contamination where surface and ground waters interconnect.

Pesticide manufacturing and formulating facilities as well as industrial users of pesticides are subject to the NPDES permit requirements. In late 1985, EPA issued effluent guidelines specifically for the pesticides industry which detail the allowable levels of pesticide ingredients in the waste stream based on the availability of treatment technology to remove them.

E. Resource Conservation and Recovery Act (RCRA)

Hazardous Waste Program (Subtitle C)

In 1976, the U.S. Congress passed the Resource Conservation and Recovery Act (RCRA) which amended the Solid Waste Disposal Act (SWDA). This legislation regulates disposal of waste, including pesticides which may create a hazard, to assure minimum effects on human health and the environment. RCRA places the burden of protecting the environment on all users and handlers of hazardous materials, and such material may include the active and/or inert ingredients of pesticide products.

The marketing and use of pesticides is regulated by EPA under FIFRA and by the States under applicable laws and regulations. However, once pesticide applications are completed, any excess pesticide concentrate, unapplied diluted pesticide, or discarded pesticide containers may also be regulated as waste (and some as hazardous wastes) under RCRA.

While most of the pesticide products sold in the U.S. are not regulated as hazardous waste, some are considered toxic waste ("toxic commercial products") or acutely toxic waste ("acutely hazardous commercial-chemical products") by virtue of their chemical and toxicity characteristics. Such pesticides are included on the RCRA F and E lists respectively. Pesticide-containing wastes that are considered hazardous wastes under RCRA are subject to extensive regulatory requirements governing storage, transportation, treatment, and disposal, and severe penalties may be imposed in the event of violation.

The matter of appropriate disposal of all pesticide products is addressed through product labeling. Under FIFRA, all pesticide products must bear specific label instructions covering storage and disposal. Such instructions are tailored to reflect the pesticide's waste classification under RCRA.

Not all pesticide uses or users are subject to the extensive RCRA waste control requirements. Household wastes, for example, are specifically excluded from RCRA jurisdication. Most farmers also are exempt from the hazardous waste "generator" requirements of RCRA, provided that they triple-rinse empty pesticide containers and dispose of any pesticide residues on their own property and in a manner consistent with the disposal instructions on the pesticide label. Commercial applicators are not automatically exempted, but are under RCRA's jurisdiction only if they generate more than 100 kilograms of regulated wastes per month. Otherwise, they are considered "Small Quantity Generators," and need only dispose of hazardous wastes in a responsible manner as reflected by the product labeling.

Underground Storage Tanks (Subtitle I)

Leaks from underground storage tanks have caused groundwater contamination in many areas of the country. In 1984, Congress amended RCRA requiring EPA to established a regulatory program for prevention, detection, and correction of leaks from underground tanks storing motor fuels and any chemical on the "CERCLA list" of toxic substances, which includes many pesticides. Their storage in underground tanks will be governed by the regulations as they are issued. This will control one potential source of pesticide contamination of ground water.

F. Comprehensive Emergency Response, Compensation and Liability Act (CERCLA)

The Comprehensive Emergency Response, Compensation and Liability Act of 1980 establishes a trust fund (Superfund) to finance government responses to releases, or threats of releases, of hazardous substances that may harm health or the environment. The Act also authorizes enforcement against those responsible for the release to require cleanup or to recover the government's cost of cleaning up. The Act directs EPA to identify a priority list of at least 400 sites as candidates for remedial action.

At the present time, 124 pesticides are listed as hazardous substances under CERCLA. Releases of listed pesticides which exceed the reportable quantity must be reported immediately to the National Response Center. Reportable quantities are one pound unless a different quantity has been established by regulation. The reporting requirement does not apply to the application of a pesticide or to releases from handling or storing a pesticide by an agricultural producer. The Agency may respond to incidents involving other pesticides if they present an imminent and substantial danger to the public health or welfare.

If ground-water contamination results from lawful application of pesticides, the law specifically precludes the use of CERCLA cost recovery authorities against pesticide applicators or private users who may be responsible even if their actions can be fully documented. While the law is clear regarding cost recovery from pesticide applicators, it does not expressly preclude use of the Fund for removal, remedial response, or restoration of the ground water. Several sites contaminated by pesticides have been proposed for the National Priority List. In general, however, EPA currently does not plan to initiate CERCLA responses for sites contaminated by pesticides since the number of sites is potentially very large and may impose a

disproportionate demand upon the Fund. It should be noted that nothing in the present law precludes use of enforcement and cost recovery authorities or Fund expenditures to clean up pesticide contamination sites caused by a spill, leak, improper disposal, or other activity not a part of lawful pesticide application.

II. Programs of Other Federal Agencies

A variety of Federal agencies support programs that can help address the problem of pesticides in ground water. Such Federal agencies as the U.S. Forest Service, Bureau of Land Management, Fish and Wildlife Service, and National Park Service manage vast areas of public land. Their use of pesticides to control insects and weeds on these landholdings may affect ground-water quality. In addition, these and other Federal agencies, such as the Tennessee Valley Authority and U.S. Geological Survey, often perform studies and projects which can support efforts to address pesticides in ground water. These agencies participate in the EPA-sponsored Interagency Committee on Ground-Water Protection, and are increasingly emphasizing ground-water protection needs in their own operations.

This discussion focuses on the programs of the U.S. Department of Agriculture (USDA), since USDA provides technical assistance to individual landowners and a range of incentives that affect the way landowners choose to manage their land. Ultimately, landowners make choices regarding pesticide use and land management practices at a site-specific level. The agencies advising them play a significant role in ensuring that landowners make environmentally sound decisions.

Recognizing the potential for ground-water contamination from agricultural activities, the USDA, under the direction of the USDA Natural Resources and Environment Commitee, has begun a departmental analysis of the seriousness of ground-water problems related to agriculture and of the programs that deal with those problems. USDA officials anticipate that program priorities and targeting, as well as eligibility requirements for some assistance programs, may be adjusted to help address ground-water protection needs.

A. USDA Extension Service

The USDA Extension Service (USDA-ES) is part of a three-way partnership (Federal, State, and county) known as the Cooperative Extension Service (CES). The basic mission of CES is to improve American agriculture and strengthen American families and communities through the dissemination and application of research-generated knowledge and leadership techniques. The Federal partner -- the USDA Extension Service -- provides support for the State Cooperative Extension organizations by overseeing the distribution of Federal funds, reviewing CES programs, and informing States about Federal priorities and programs.

As USDA's educational arm, CES provides information, materials, publications, and advice to citizens. It plays a vital role in educating pesticide users in the safe and proper use of pesticides. In cooperation with EPA, CES conducts the training program that pesticide applicators must complete to be certified for using restricted use pesticides. These training programs are viewed as a principal mechanism which can be used to train applicators in ground-water concerns, and current plans for the program include developing a unit on ground-water protection. Extension agents also provide advice on pest control and individual pesticides, and in many States provide Integrated Pest Management services and advice.

Recently, the Extension Service established a national Ground-Water Task Force. It surveyed Extension leaders across the country regarding current activities and future Extension programming needs related to ground water. Pesticide use and application ranked as the highest priority, followed by nutrient use and application, animal wastes, and on-site sewage (septic tanks). The Extension leaders also see a role for Extension in providing public education regarding the health effects of contamination. Other major needs are additional staff training and better access to technical expertise so that Extension staff can fulfill their educational role in support of ground-water protection.

Among current Extension projects addressing pesticides in ground water are initiatives in New York and Wisconsin to develop maps on the risk of ground-water contamination using information from soil surveys and on the properties of commonly used chemicals. Nebraska is developing an educational program on chemigation and ground-water protection in general for national distribution. An educational component is being added to Iowa's Big Springs Demonstration Project for ground-water protection, and the State Agricultural Experiment Stations are conducting a joint initiative on ground-water education and research.

B. USDA Soil Conservation Service

The Soil Conservation Service (SCS) was created in 1936 to control erosion that was stripping topsoil from America's farms at a dangerous rate. Since then, the SCS mission has expanded to cover three major areas: soil and water conservation, natural resource surveys, and rural community protection and development. Since 1982, SCS has recognized water as an inseparable component of the resource base and has sought to integrate water quality concerns into all ongoing SCS programs and activities. Among other activities, the SCS provides direct technical assistance to landowners in designing and carrying out plans for conserving soil and protecting water quality.

The traditional focus of SCS activities has been on protecting topsoil. More recently, SCS has turned its attention to protecting surface and ground water quality as well. Several SCS activities will directly or indirectly support efforts to deal with pesticides in ground water.

SCS soil surveys, completed for most counties, provide detailed information on soils as well as other information important for assessing vulnerability to ground-water contamination from the application of agricultural chemicals. SCS is initiating field studies on pesticides in ground water, creating a position for a technical specialist on interactions between pesticides and ground water, and developing a training program on this subject. Other activities include formulating an SCS Geographical Information System; developing data on both the cost-effectiveness of various measures for managing nonpoint sources and on the quantification of problems and impacts; ongoing water quality training for Federal, State and local officials; and reassessment and review of SCS program targeting, resource, and incentives issues in light of water quality concerns.

Several other SCS-supported projects also address issues pertaining to pesticides in ground water. SCS is cooperating with the University of Rhode Island in a study of the transport of agricultural chemicals into ground water under various crops and land treatment practices. In South Dakota, SCS is studying nutrient and pesticide management in combination with potentials for conservation tillage. In Wisconsin, the Sands Resource Conservation and Development Project is working with farmers and other residents to reduce contamination of community water supplies from agricultural chemicals. Where computers are available at the field level, SCS also occasionally uses a model developed by the Agricultural Research Service that can estimate the potential for ground-water contamination as individual conservation plans are developed.

C. USDA Agricultural Stabilization and Conservation Service

The Agricultural Stabilization and Conservation Service (ASCS) administers farm commodity, conservation, environmental protection, and emergency programs related to agricultural production across the nation. Within ASCS, the Agricultural Conservation Program (ACP) is charged with helping prevent soil erosion and water pollution, protecting and improving productive farm and ranch land, conserving water used in agriculture, preserving and developing wildlife habitat, and encouraging energy conservation measures. In carrying out this responsibility, ASCS provides cost-sharing to farmers and ranchers to carry out conservation and environmental protection practices that result in long-term public benefits, but that the farmer or rancher is unable to undertake without financial and technical assistance.

Controlling pollution from nonpoint sources is currently recognized as one of the primary purposes eligible for cost-sharing assistance. ASCS is working with SCS and EPA to develop quantifiable data that can be collected in the Conservation Reporting and Evaluation System to provide a better tool for monitoring and evaluating efforts to control nonpoint sources. ASCS encourages local, State, and national conservation review groups to identify and rank known nonpoint source problem areas, including ground-water problems; develop any special practices needed; and to propose projects for special funding consideration. ASCS also uses data from the Rural Clean Water Program, including several projects with ground-water quality components, to aid in evaluating the effectiveness of best management practices.

D. USDA Agricultural Research Service

The Agricultural Research Service (ARS) devotes a major portion of its efforts toward control of chemical sources of pollution. The principal thrusts of these efforts are toward improved chemical use efficiency and development of alternatives to the use of chemical pesticides, including breeding of disease resistant crops and biological control of insects. ARS is also investigating nitrate and pesticide movement through soils.

Research on pesticides and ground water is a relatively new but rapidly expanding field. To facilitate sharing of information among researchers and users of research results, the ARS established a new computer information bank containing brief descriptions of pesticides and ground water projects. All Federal agencies have already placed projects into the system and efforts are now underway to obtain and include projects from such other research institutions as the land grant universities.

E. U.S. Geological Survey

The U.S. Geological Survey (USGS) of the U.S. Department of the Interior is the principal Federal agency conducting ground-water resources investigations, which it performs through a variety of Water Resources Division programs. A Federal-State cooperative program was developed to support hydrologic data collection activities and water resource investigations, with costs shared equally by the USGS and cooperating State and local agencies. Much of the information used for planning, developing, and managing the nation's water resources is derived through this program. Areas of investigation are selected through a collaborative effort between USGS personnel, with support from outside contractors for drilling and sampling.

The USGS has also proposed a program to describe water quality on a national scale, called the National Water Quality Assessment Program (NAWQAP). Other existing USGS activities include the Regional Aquifer System Analysis Program (RASA), which focuses on describing ground-water flow and natural ground-water chemistry in the systems; a National Water Resources Conditions Program (NWRC) designed to provide information about the availability, quantity, quality, and use of water resources; and a Toxic Waste Ground-Water Contamination Program, which supports regional field studies, intensive investigations, and research focused on specific contaminants, and provides Federal and State agencies with earth-science information that relates land use and hydrogeology to contaminant fate in ground water.

Recent activities under RASA include studies of aquifer systems in the northern Great Plans, the High Plains, California's Central Valley and the Snake River Plain. NWRC recently developed an information system to support the identification of water issues, characterize current water conditions, and evaluate the water resources assessment activities of other agencies. The Toxic Waste Program is investigating the ground-water transport mechanisms under field conditions for contaminants such as oil, gasoline, organic chemicals (e.g., pesticides and solvents), sewage, and heavy metals.

The Department of Interior and EPA have signed a Memorandum of Understanding (MOU) which covers the two agencies' relationships and activities related to ground water. Under this MOU, the USGS and EPA's Office of Pesticide Programs signed an interagency agreement in 1984 to allow and promote cooperation in the gathering of information on and assessment of the hydrogeology of various areas of the nation. This agreement supports projects that address the vulnerability of the nation's groundwater supplies to pesticide leaching.

III. State Programs Addressing Pesticides in Ground Water

While the Federal government sets national policy as well as standards and regulations, the States are generally responsible for implementing them. Federal efforts to address pesticides in ground water must consider existing State programs available for implementation, the effect of Federal actions on State organizations and programs, and what support States will need to carry out their implementation responsibilities.

Because of the variety of State agencies involved and the limited degree of coordination among them in many States, it is difficult to obtain a definitive picture of past and existing State efforts to address pesticides in ground water at this time. During the summer of 1985, EPA conducted a limited review of written reports on the subject, grant activities under several EPA programs, and other materials to compile a summary of known State programs. EPA Regional office staff reviewed the material in the draft summaries with key officials in each State.

While this compilation of information from a variety of sources is recognized as being incomplete for some individual State programs, when analyzed together, some general conclusions can be drawn. Following is a preliminary analysis of the status of State programs for pesticides in ground water. Individual State summaries are being published in a separate document.

Perhaps the most important conclusion to be drawn is that while the majority of States recognize the potential significance of the pesticides in ground water problem, efforts to address the problem have been fragmented. Often, the agency responsible for pesticides control is housed in the State agriculture department while primary responsibility for water quality and waste disposal programs is located in a State environmental protection agency. Responsibility for assuring safe drinking water often rests in still another agency, such as a public health department. Each agency may have performed tasks related to pesticides in ground water, but there has been limited coordination among them. This situation mirrors in many respects the need for coordination between EPA programs and other Federal agencies at the national level.

Most of the monitoring States have performed thus far for pesticides in ground water has been in response to a known or suspected problem. Of the 24 States which reported specific findings, the most frequently identified pesticides were aldicard, EDB, and atrazine. The increased concern about ground water contamination generally and the recognition of pesticides as a potential contaminant have led several States to initiate more comprehensive monitoring programs. These efforts, still largely in the planning stage, focus monitoring in areas of pesticide usage where the ground water is considered to be most vulnerable to contamination.

Many States have initiated user awareness programs to address at least some aspects of the problem. Most notable are "Amnesty Day" programs, in which State and local organizers arrange for the collection and safe disposal of unwanted pesticide products from households and farms. States have also begun educational programs to increase understanding of ground water and how it may become contaminated by agricultural practices.

While many States have at least some activities addressing pesticide contamination, only a few have begun efforts that could be defined as prevention or control programs. Several States have established or are developing regulatory programs to require anti-backsiphoning devices and other safety measures on chemigation systems which, if not properly equipped and calibrated, can result in ground water contamination. [Note: EPA is also proposing requirements for chemigation systems.]

A handful of States are preparing for implementation of new laws either governing ground-water protection generally, including pesticide problems, or laws dealing with pesticide contamination specifically. Since these programs are in the formative stage, the exact nature of the controls or management schemes that will be used are still undetermined. Some anticipate more vigorous State registration of pesticides to keep those which threaten ground water from being used in the State. At least one State law suggests more extensive research and implementation of Integrated Pest Management as part of the protection program. Other controls being considered or implemented include requiring buffer zones around wells, requiring prior approval for the use of certain pesticides, allowing use only under severe restrictions, and banning the use of pesticides in areas where monitoring reveals that levels of health concern are being approached. In developing these programs, one of the first steps States are taking is identifying areas where pesticide contamination of ground water is most likely to be a problem.

For many years, States did a limited amount of ground water protection plannning using funds under Sections 208, 106 and 205(j) of the Clean Water Act. With the additional impetus in 1985 and 1986 of special Section 106 grants for ground water, virtually all States are now developing and implementing ground-water protection strategies addressing all sources of contamination, including pesticides. Many States are reviewing statutory and regulatory authorities to address pesticides concerns as part of this effort. Many State plans for ground-water monitoring also include pesticides. The only grant funds under FIFRA for State pesticide programs directly are earmarked for enforcement and certification of pesticide applicators. A few States are using enforcement funds to help support investigation of ground water contamination incidents; other States have begun incorporating educational materials on ground water into certification training programs.

Despite the general need for better coordination among agencies at the State (and Federal) level, there are several exceptions. For example, ongoing projects to control nonpoint sources of water quality problems at the substate level demonstrate a significant amount of cooperation between Federal, State, and local agencies. Projects typically include providing technical and cost-sharing assistance to landowners for the installation of best management practices, many of which protect both surface and ground-water quality. In some projects, participation in Integrated Pest Management programs is a condition of receiving cost-sharing assistance.

CHAPTER THREE

ASSESSING GROUND WATER IMPACTS
AND HEALTH SIGNIFICANCE

The primary reason there is concern about pesticide contamination of ground water is the potential risks it my pose to human health. To address this concern, the presence and extent of any actual or potential risks posed by such contamination must be assessed. Such assessments must not only identify potential risk, but also strive to understand the underlying causes of contamination. This latter objective is necessary, for knowledge of causal factors provides the basis for both determining appropriate control measures and developing the capability to predict risks prior to their realization.

To assess the health risks posed by pesticides, information is required on both the inherent toxicity of the chemical and the extent of contact or exposure to the agent. Most of the information on the toxicity of a pesticide comes primarily from laboratory animal testing, usually required of the manufacturer for EPA registration. Exposure information can come from studies of actual occurrences of environmental contamination and exposures. Estimates of exposures can also be derived from analyzing the physical and chemical properties of a pesticide as well as its current or intended use; these factors are key determinants of the fate of a pesticide once it is released into the environment.

The primary purpose of this section is to describe the information that is critical for identifying or predicting the risks of pesticide contamination of ground water and for developing appropriate preventive or remedial measures. The first part of this chapter focuses on the information required to identify or predict ground water contamination and subsequent human exposures. The second part focuses on the toxicity information required to assess the health consequences of any identified or predicted exposure.

I. Assessing Ground Water Impacts of Pesticides

Once ground water is contaminated, many years may have to pass before natural processes can return it to its previous state. Attempts to accelerate the "cleansing" of an aquifer can prove very costly, if not impossible. Contamination of an aquifer today could preclude its use as a drinking water source for some time into the future. Even when treatment of the water is technically feasible, the costs may be prohibitively expensive, particularly for small water systems and individual well owners. Ground water deserves protection as a natural resource for both current and future use. It may not be necessary (and sometimes, not possible) to determine the extent of exposures that could result from a current or potential occurrence of ground-water contamination before remedial or preventive action should be initiated.

Some contamination of ground water by pesticides may, however, be an unavoidable side-effect of the use of these chemicals. Such contamination may be acceptable in cases where there is confidence that no undue risk to human health or the environment would result either now or in the foreseeable future. In order to draw conclusions as to presence or absence of any unreasonable risk, the exposures resulting from an identified or predicted incidence of ground-water contamination must be assessed.

As will be shown by the discussion below, significant strides have already been made in understanding the potential for ground-water contamination by pesticides. However, there are also many inherent difficulties in assessing this potential and limits to the amount of actual monitoring information that is feasible to collect. Consequently, regulatory decision-makers base their actions on a mix of information on both known contamination and predictions of potential drinking water exposure which could result from the use of pesticides.

A. Information Requirements for Contamination and Exposure Assessment

Determining whether ground water contamination could occur from the use of pesticides requires information on:

- What pesticides have the potential to leach to ground water?

  Given enough time and the right conditions, many pesticides are capable of leaching through soil into ground water. However, some pesticides degrade too quickly or move too slowly in soil to be considered much of a threat; others have the capability to move down into ground water rapidly and intact. The chemical and physical characteristics of a pesticide determine its potential as a "leacher."

- What conditions are necessary or enhance the potential for a pesticide to leach to ground water?

  While a pesticide's chemical and physical characteristics determine its potential as a leacher, a number of factors are involved in determining whether the pesticide will actually leach to ground water. The way a pesticide is applied, the environment to which it is applied (soil, rock, topography, water table, weather, type of crop, etc.), and the other farming activities being practiced (e.g., irrigation) are just some of the major determinants in the fate of a pesticide once released into the environment.

- What conditions other than "normal leaching" can result in ground-water contamination?

  Certain pesticide uses (e.g., biocides in wells) can result in ground-water contamination by pesticides which are not usually thought of as being leachers. Spills or careless disposal of pesticides could also result in "non-leachers" contaminating ground water.

- Where has pesticide contamination occurred or is contamination a potential threat?

  Years of pesticide use have resulted in contamination of ground water in several areas around the country. Efforts must be made to identify other areas where ground-water contamination by pesticides may require remedial action. Furthermore, areas vulnerable to ground-water contamination and areas where pesticides with leaching potential may be in use must be identified to support decisions on preventive measures.

Concern for the exposures resulting from ground-water contamination by pesticides will require the above information as well as an understanding of:

- Pesticide movement and persistence once they reach an aquifer.

  While this information is needed in designing a sampling scheme for assessing ground-water contamination, it becomes much more important when attempting to assess the likelihood of contamination reaching drinking water taps at levels of concern. To determine this likelihood, it is necessary to identify the dimensions of a potential contamination "plume" and the wells which draw water from it.

- Who uses, and how frequently, ground water supplies that are identified or predicted to be contaminated at levels of concern.

  Only general estimates of the number of people likely to draw on contaminated ground waters may be required to support EPA registration decisions. Much more precise determinations of the extent of exposures may be required at the local level to support remedial or prevention decisions.

Note: (While the above information on contamination and exposure information is critical, the reader is reminded of the importance of toxicity information for assessing risks and deciding upon regulatory and response actions. Toxicity considerations are discussed in the next section of this chapter.)

B. Tools to Assess Contamination and Exposures

To meet the information and assessment needs stated above, EPA relies on two primary tools: monitoring and predictive modeling.

The Role of Monitoring. Monitoring provides information on the actual presence and magnitude of pesticides in soil, in underlying ground water, at drinking water taps, or in any other media that is accessible and relevant to issues of concern. Monitoring studies can range from small-scale, intensive field studies that involve only one pesticide to large-scale, perhaps national, surveys which analyze for a multitude of pesticide residues.

Small-scale studies take place on fields which are the size of a research plot, usually less than 25 acres. Both prospective and retrospective monitoring are conducted in small-scale studies. A retrospective small-scale monitoring study is a snapshot in time following the long-term use of a pesticide on a field. A prospective study consists of continual monitoring of a pesticide that begins with its application to a "clean" test site (i.e., no previous use of the pesticide in question). The prospective study will monitor for the pesticide as it moves through the unsaturated zone and into the aquifer. A prospective study may also follow the fate of the pesticide once it is introduced into the aquifer.

Generally, a retrospective study is conducted to examine an existing situation and determine if contamination has resulted from past practices. A prospective study aims more toward gaining understanding of the basic process of pesticide leaching and movement in the aquifer. Prospective studies are used to help validate predictive models and to determine the conditions under which a specific pesticide will leach.

Large-scale surveys refers to broad retrospective studies (usually basin, Statewide, or larger) from which conclusions can be drawn about the number and concentrations of pesticides in specific types of wells (e.g., public water supply wells) or in specific geographic areas (e.g., truck farming on the mid-Atlantic Coastal Plain).

Monitoring to detect detailed variations in ground-water quality over large areas is not feasible. Contaminants are usually so localized around their sources that a network of sample wells is unlikely to detect the complete dimensions.

Hence, large-scale monitoring efforts depend, in part, on statistical designs to estimate the general extent of occurrence of contaminants in wells over a large area. Large-scale efforts also depend on models to provide inferences as to the dimensions of contamination.

The Role of Modeling. The need to understand the complexity of the interacting factors that affect pesticide movement and persistence in soil and in ground water has led to the development of mathematical models that quantify and integrate these factors. These models attempt to simulate the fate of pesticides in the soil environment and their movement to and within ground water. The two general types of models are ranking models and dynamic fate models.

The ranking models assign relative weights to a series of key factors in terms of their importance in determining the potential for ground-water contamination. Such models have been used by EPA to identify and rank pesticides for their potential to leach or locations for their vulnerablity to such leaching.

Dynamic fate models are much more complex than static models for they attempt to simulate the transport and transformation of pesticides in the environment over time. They thus require sophisticated mathematical formulations and are usually set up on a computer. Dynamic models for predicting ground-water contamination by pesticides have been developed for the saturated zone (below the water table) and the unsaturated zone (located between the ground surface and above the water table).

- Unsaturated zone fate models predict the amount of pesticide to leach below a certain point in the soil, either below the root zone, below one or two meters, etc. Such models try to predict the solution concentration of a pesticide at a certain depth over time. Or, a multi-year model simulation can be interpreted statistically to provide probabilities of certain occurrences. For example, one may predict that 15% or more of an applied pesticide will leach below the root zone 10% of the time. This "10% of the time" may be interpreted as the worst year in ten.

- Saturated zone fate models attempt to predict the horizontal and vertical movement of pesticides in and among aquifers, or the saturated zone. The saturated zone, lying under the unsaturated zone, has all spaces or pores filled with water. Output from an unsaturated zone fate model can be direct input for a saturated zone fate model. Link-ups between unsaturated and saturated zone models attempt to provide a complete picture of the distance a pesticide will move from its application point and the alterations it will undergo as it moves through the soil and into and through ground water. Saturated zone models can be useful for making comparisons among pesticides and different hydrogeologic settings.

Interaction of Modeling and Monitoring. Monitoring shares with modeling a common underlying purpose of providing quantitative information on pesticide contamination of ground water. While modeling is a mathematical approach aimed at predicting the fate of pesticides in soil and ground water, monitoring attempts to measure the actual presence and magnitude of pesticides in these media. Monitoring and modeling complement one another. Modeling can be used to optimize the design of monitoring efforts, helping to limit what needs to be monitored and where. It is also helpful in organizing and interpreting the results of a monitoring effort. In turn, monitoring provides the information necessary to develop, improve, and validate models.

Together, monitoring and modeling provide the basis for identifying existing ground-water contamination and resulting exposures and support decisions on remedial actions. These tools can also be used to predict the likelihood of further risks and provide the basis for preventative measures, both at the national and local levels.

C. Current Efforts and Understanding

Although ground-water contamination by pesticides is a relatively recent public concern, there has been a significant history of research about the environmental fate of pesticides that has either directly or indirectly provided some understanding of the problem. In particular, there has been a great deal of work on the fate of pesticides in soil. As a result, we generally know what types of pesticides have the potential to leach to ground water and what conditions (i.e., type of soil, hydrology, application method, etc.) determine or influence the likelihood of a pesticide to leach. We also know of certain "abnormal situations" (i.e., spills or disposal) or uses (e.g., biocides in wells) that can result in serious point sources of pesticide contamination of ground water. On the other hand, as a result of limited monitoring and ground-water fate modeling, we have a basic information gap as to where pesticide contamination has or could occur and the extent of subsequent exposures.

Following is a summary of what is currently known about pesticides in ground water and the current efforts underway to improve our understanding.

The Leachers. As stated above, the study of pesticides in soil and the corresponding development of soil fate models pre-dates the concern for ground-water contamination. As a result, we have a better understanding of the relative leaching potential of various pesticide classes than perhaps any other aspect of the problem. Recent monitoring of ground water has provided data that has improved and confirmed our understanding of what makes a pesticide a high potential leacher. The following are the important physical and chemical characteristics of a pesticide leacher:

- Water solubility: the propensity for a pesticide to dissolve in water. The higher a pesticide's water solubility, the greater the amount of pesticide that can be carried in solution to ground water. Water solubility of greater than 30ppm has been identified as a "flag" for a possible pesticide "leacher."

- Soil adsorption: the propensity of a pesticide to "stick" to soil particles, which is defined as the ratio of the pesticide concentration in soil (C_s) to the pesticide concentration in water ($K_d; C_s/C_w$). There are different mechanisms for pesticide adsorption in soils, with particular important differences occurring in clays as opposed to organic soil matter. A second measure, K_{oc}, is used to help characterize the mechanism of adsorption. K_{oc} is a measure of the pesticide adsorption to the organic part of the soil. The lower a pesticide's K_d and K_{oc} values, the more likely these chemicals will not be adsorbed to soil particles but leach to ground water. Of the pesticides found in ground water to date, most have had K_d values of less than 5, and usually less than 1.0. These ground-water contaminants have also generally been shown to have K_{oc} values of less than 300.

- Volatility: the propensity for a pesticide to disperse into the air is primarily a function of the vapor pressure of the chemical and is strongly influenced by environmental conditions (e.g., temperature, wind speed, etc.). Nonvolatile pesticides such as DDT have low vapor pressures which will increase their persistence on and in the soil. Pesticides with high vapor pressures have not been considered a threat to ground water because they rapidly volatilize from the soil surface. However, the major ground water problems caused by the very volatile pesticides EDB, DBCP, and DCP have dispelled this notion. Contamination by these volatile pesticides has been blamed on their mode of application which is direct injection into the soil. It has also become apparent that the actual volatility of these pesticides when present in water is critically changed.

This aqueous volatility is determined by dividing a chemical's vapor pressure by its solubility; this value is termed Henry's Law Constant (H). A compound such as DBCP has a very high vapor pressure but is also very water soluble. High water solubility can cause high vapor pressure chemicals to remain in the soil, particularly when these pesticides are applied just prior to irrigation or rainfall.

- Soil dissipation: a simplified, general measure of a pesticide's persistence in soil usually measured as the length of time required for dissipation of one-half the concentration of a pesticide and often referred to as a pesticide's "soil half-life." The soil half-life of a pesticide can be derived from either laboratory or field studies, but care must be taken in recording the conditions of the test including temperature, type of soil, soil moisture, etc.

  Soil dissipation is dependent on a number of environmental processes including vaporization and several decomposition processes that cause chemical breakdown, particularly hydrolysis, photolysis and microbial transformation. Hydrolysis is the reaction of a chemical with water. Photolysis is the breakdown of a chemical from exposure to the energy of the sun. And, microbial transformations result from the metabolic activities of microrganisms within the soil. When a pesticide resists these decomposition processes and does not readily evaporate, it will have a long soil half-life, increasing its potential as a threat to ground water. This is particularly true if the same pesticide is highly soluable and does not readily adsorb to the soil particles. Pesticides with half-lifes greater than 2 or 3 weeks should be carefully assessed.

Concern for ground-water contamination by pesticides has led EPA to focus more attention on identifying potential leachers through the Agency's pesticide registration and re-registration process. EPA has begun to examine every pesticide for chemical and physical properties that would, as described above, indicate their potential to leach. Table 3 provides a summary of the threshold values for these key factors that would indicate a pesticide has a high potential to leach. For pesticides identified as being potential leachers, the Agency will review their use patterns to assess if other factors may exist that would increase the likelihood of their leaching (see below).

Soil Factors Affecting Leaching. The type of soil that receives a pesticide can greatly affect the likelihood of any leaching. The properties of the soil form one of the two most important categories of factors affecting leaching potential. These soil factors include:

- Clay content: refers to the presence of clay minerals. Clay minerals contribute to cation exchange capacity, or the ability of the soil to adsorb positively-charged molecules (i.e. cations). Positively-charged pesticides will thus be adsorbed to soil containing negatively-charged clay particles. Clay soils also have a high surface area which further contributes to adsorption capacity. Adsorption onto clay colloids leads to chemical degradation and inactivation of some pesticides, but it inhibits degradation of others.

- Organic matter content: also contributes to adsorption of pesticides in soil. Organic matter content affects bioactivity, bioaccumulation, biodegradability, leachability, and volatility of pesticides. Soils with high organic content adsorb pesticides and therefore inhibit their movement into ground water. However, pesticides which are highly adsorbed to organic soil will often be applied at higher rates by a farmer in order to compensate for the adsorbed portion. There is evidence that pesticide residues adsorbed to high organic (humus) soils may eventually be released, intact, to ground water when microbial degradation of the humus occurs.

- Soil texture: also influences pesticide leaching. Texture refers to the percent sand, silt, and clay. Leaching is more rapid and deeper in coarse or light-textured sandy soils than in fine or heavy-textured clayed soils.

- Soil structure: refers to the way soil grains are grouped together into larger pieces or aggregates -- platy, prismatic, blocky, or granular. Structure is affected by texture and percent organic matter. Pesticides and water can seep, unimpeded, through seams between the aggregates.

- Porosity: is a function of total pore space, pore size, and pore size distribution and is determined by soil texture, structure, and particle shape. Pesticide transport is more rapid through porous soils.

- Soil moisture: refers to the presence of water in soil. The water in soil ultimately transports pesticides that are not adsorbed into the water table below. Upward movement may also occur through capillary action and by a process termed evapotranspiration in which water in the soil is lost to the air.

- Depth to ground water: the distance a pesticide must travel through the soil or underlying foundation material to reach ground water is, of course, a key determinant in whether contamination will occur at a particular site.

Application Factors Affecting Leaching. The other category of factors determining pesticide leaching involves the methods and conditions of pesticide application. These factors include:

- Local climatic conditions: the degree of pesticide leaching at a particular site can be directly dependent on the amount of local rainfall. The temperature of the soil and surrounding air at a site can also greatly affect the processes that result in a pesticide's movement and degradation in the environment.

- Rate of application: how much and how often a pesticide is applied to the soil can be the critical determinant in ground-water contamination.

- Timing of application: when a pesticide is applied can be a major factor depending on local environmental conditions and temperature and rainfall.

- Method of application: a pesticide can be applied to crops by aerial spraying, topsoil application (granular, dust, or liquid formulations), soil injection, soil incorporation, or through irrigation. Soil injection and incorporation are generally considered to pose the greatest likelihood for ground-water contamination problems.

The application of pesticides through irrigation, often referred to as chemigation, can also be a significant source of ground-water contamination. An irrigation pump may shut down due to a mechanical or electrical failure while the pesticide-adding equipment continues to operate. This malfunction can cause a backflow of pesticides into the well or cause highly concentrated pesticide levels being applied to a field.

- Irrigation practices: increase the soil moisture content and flow through the soil, raising the potential for chemical leaching. Irrigation can decrease the amount of volatilization of some pesticides from the soil. Excess irrigation can also carry pesticides down the well casings of abandoned or poorly constructed wells, directly injecting contaminants into an aquifer. The use of drainage tiles can also lead to direct input of pesticides into ground water regardless of their leaching potential.

- Cultivation practices: conservation tillage or no-till practices used to decrease soil erosion and pollutant runoff into streams will increase water infiltration and hence potential for pesticides to leach. Furthermore, these practices usually require increased use of herbicides which may leach. Other soil conservation practices designed to inhibit runoff may also increase infiltration.

- Spillage/disposal: can result in high concentrations of pesticides in soil. These "slugs" can overwhelm normal decomposition processes and soil adsorption capacity, resulting in high potential for ground-water contamination. Spillage, in particular, can be a common problem where pesticide mixing and loading take place.

  Handling of unwanted pesticides and empty containers may also pose problems. Rinse water from the cleaning of spray equipment may also be washed into the soil; the large amounts of contaminated water associated with this practice can increase pesticide leaching.

- Non-agricultural applications: pesticides used to control termites are generally injected directly into foundations or soil and can result in ground-water contamination due to the large amounts used and the methods of and potential problems involved in application. Oil and gas drilling operations can cause contamination through the use of pesticides to combat build-up of scale in well casings.

The textile industry uses large volumes of pesticides to treat finished products for odor control and fungus growth; poor handling and mixing practices in this industry could pose threats to ground water. Lastly, pesticides are widely used to control insect and weed pests on highway and utility rights of way and on urban lawns.

Table 3: Chemical/Physical Properties of Pesticides: Values Which Indicate Potential for Ground-Water Contamination

Water solubility -- greater than 30 ppm

K_d -- less than 5, usually less than 1

K_{oc} -- less than 300-500

Henry's Law Constant -- less than 10^{-2} atm-m^{-3} mol

Speculation -- negatively charged, fully or partially at ambient pH

Hydrolysis half-life -- greater than 25 weeks

Photolysis half-life -- greater than 1 week

Field dissipation half-life -- greater than 3 weeks

D. Efforts to Improve the Information Base

Pesticide Leaching. EPA is improving the information base on factors affecting pesticide leaching by: (1) gathering additional information on the use practices of individual pesticides; (2) developing and validating models that attempt to simulate pesticide leaching under various conditions, and (3) supporting ground-water monitoring studies.

For any pesticide that has the physical and chemical characteristics of a potential leacher, EPA requires the pesticide registrant to submit detailed information on the use history of the chemical. For existing pesticides, the registrant may have to provide information on: the crops and geographic areas where the chemical has been used over the past five years; the amounts applied; and the types of application methods employed. The registrant may also be required to submit key factor information on the soil and hydrogeology (discussed in next section) of the area where the pesticide has been or is to be used.

In addition to gaining information on the specific use practices of individual pesticides, numerous efforts are underway by EPA and others to improve basic understanding of the processes that affect the potential for pesticides to contaminate ground water. These efforts are aimed primarily at furthering the development and validation of the models used to predict the movement of pesticides into ground water.

Over the last 14 years, EPA has developed two leaching models, PESTANS and PRZM, to assess the potential for pesticides to reach ground water. Extensive work to test and validate these models has been underway for a number of years at EPA's Doughtery Plains Project in Georgia. The major technical focus of this effort includes: testing model outputs against varying hydrogeological conditions and soil properties; testing individual process descriptions for comparison of relative importance of key factors; determining impacts of spatial variability; and formulating additional processes including those needed to link these unsaturated zone models to saturated zone models. Field testing at Doughtery Plains will be completed by EPA in 1987.

EPA is also turning to the U.S. Geological Survey (USGS) to gain field data for the testing of predictive modeling capabilities. USGS is a natural resource research and investigation agency responsible for developing basic scientific information on the ground-water environment. USGS collects basic data on the quantity and quality of the nation's ground-water resources, both on a broad-scale and on a local or [illegible] scale where particular problems have been identified. EPA has agreements with USGS for several cooperative research and monitoring efforts and exchange of information in the ground-water area. Of particular note, USGS will be providing field data to EPA that should greatly assist further develoment and refinement of predictive ground-water contamination models.

In addition, EPA is also supporting work by others to develop better understanding of the problem in areas where ground-water vulnerability to pesticide contamination may be exceptionally high. For example, EPA has provided assistance to the study of Iowa's Big Spring Basin area where the ground is dominantly underlain by carbonate (limestone and dolomite) rock which holds the region's primary source of drinking water. In this area, much of the ground water lies close to the surface and the carbonate rock is highly fractured. The Big Springs Basin has karst topography where numerous sinkholes, sinking streams, and blind valleys allow surface water to move rapidly into the ground water. As a result, karst areas have been believed to be highly vulnerable to ground-water contamination. Results from the Big Springs project, however, have shown that less than a third of the pesticide levels in the area's ground water is due to the karst condition. Most of the contamination appears to be due to "normal" leaching from agricultural fields. The additional contamination due to "run-in" (i.e., contaminated surface water directly enters ground water through sinkholes) may, however, result in pesticide levels exceeding thresholds of basic concern.

EPA is also assessing the impacts of changing agricultural practices on ground water quality. Of particular interest is the increasing use of minimum or no-till practices to limit soil erosion and nonpoint source pollution of surface waters. Such practices may require a somewhat larger use of herbicides to control weeds. The heavier use of herbicides and limited runoff may actually increase pesticide leaching to ground water. EPA is using its modeling capabilities with extensive field data in a pilot assessment of the implications of such farming practices in the Eastern Cornbelt/Lake Erie Drainage Basin.

The pesticides in ground water problem is also being researched by a number of other Federal and State agencies in addition to EPA and USGS. The U.S. Department of Agriculture, through its Agricultural Research Service and through the funding of State Agricultural Experimental Stations, is a major sponsor of ground-water research. Research supported by USDA includes characterization of the source (i.e., quantities of pesticide used, agricultural practices), examining the fate of pesticides in the environment, predictive model development, monitoring protocols, assessment of remedial measures, and impact analysis. USDA will rely on its Soil Conservation Service and State Cooperative Extension Service to transfer knowledge gained through its research efforts to rural agricultural community programs in a manner relevant to local issues.

Fate of Pesticides in Ground Water. Understanding the movement and fate of pesticides once in the saturated zone or aquifer is critical to determining if contaminated ground water will reach a well -- particularly one used for drinking water. Such information is also needed in any sampling design for ground-water monitoring.

Soil or rock which transmits relatively large amounts of water is called an aquifer. Productive (high water-yielding) aquifers generally consist of unconsolidated materials (e.g., sands and gravels), permeable rock (e.g., sandstone), or rock with large fractures or cavities (e.g., limestone). Water and pollutants are transmitted more slowly and therefore over shorter distances through clays and other less permeable materials, which are called aquitards or aquicludes.

Water enters an aquifer through its recharge zone, usually a relatively flat area where the geological formation which comprises the aquifer outcrops at the ground surface. Pesticides or other pollutants spread on the ground in a recharge area will enter the aquifer if they are not adsorbed by the soil. This contamination of a recharge zone may increase with increased rainfall or irrigation. Ground-water contamination is more likely if the depth to the water table is shallow. A shallow water table is common in humid regions, especially in the spring.

Once it enters an aquifer, water flows very slowly -- typically feet per day or feet per year -- down a hydraulic gradient until it discharges into a stream, lake, ocean, or well. If the aquifer slopes beneath an overlying aquiclude and water is trapped under pressure in it, then the formation is called a confined, or artesian, aquifer. Until recently, "confined" aquifers were thought to be protected from seepage of contaminants in aquifers above and below by the intervening impermeable strata. However, there is recent evidence that organic chemicals can seep through thick clays that do prevent water penetration.

There has been a proliferation of ground-water fate models. No "best" model yet exists, and all such models require extensive calibration for any site-specific application.

Extent of Ground-Water Contamination and Exposure. As discussed in Chapter I, at present we are unable to determine the extent of the pesticides in ground water problems. While numerous studies have been conducted for a variety of purposes, they have provided information about a limited number of pesticides in specific areas.

Table 4 describes some of the current and pending efforts by EPA, USGS, and some States to monitor for pesticides in ground water. Other studies are underway in industry and in other States. Of particular interest are the large-scale surveys designed to indicate the extent of pesticide contamination in the nation as a whole and in several States (e.g., Iowa, Georgia, California).

EPA's National Survey of Pesticides in Drinking Water Wells is the Agency's major effort to understand how extensive the problem is nationwide. The survey will give us useful information about the distribution of pesticide contamination problems, some estimates of the number of people affected, and how pesticide usage and hydrogeology relate to pesticide occurrences. Approximately 50 pesticides are being monitored in 1,500 public and private wells throughout the country. The survey design calls for all counties in the U.S. to be categorized according to four classes of pesticide usage (i.e., high, medium, low, and uncommon) and three classes of ground-water vulnerability (i.e., high, medium, low). A predetermined number of counties will then be selected from each of the 12 strata in the 3x4 matrix. County segments and actual wells to be sampled will be selected based on criteria which have not yet been specified. The intent of this survey is to provide a general indication of the extent of pesticide occurrences across the country as well as occurrences in areas of particular interest (for example, farmland where pesticide usage is high and hydrogeological vulnerability to contamination is high). A final report from the national survey is expected in late 1988.

Another broad ground-water "characterization" effort is the U.S. Geological Survey's Toxic Waste-Ground-Water Contamination Program. This program will systematically investigate ground-water quality in relation to human activities, climate, and hydrogeology within 14 study areas. The intent of these studies is to help define the type of ground water problems in various areas of the country. Pesticides will be examined as well as other organic substances and trace metals. This national appraisal should be completed in 1988.

TABLE 4

SUMMARY OF EPA/USGS MONITORING FOR PESTICIDES IN GROUND WATER

PROGRAM	PURPOSE	LOCATION	PESTICIDES MONITORED	RESPONSIBILITY	STATUS	REMARKS
OPP-ODW Nat'l Survey of Pesticides in Drinking Water Wells	To determine nature & extent of pesticides in g-w nationwide and human exposure to them via drinking H2O. ODW use: develop MCLs, HAs. OPP use: Identify reg. needs, e.g. cancellations, restrictions, etc.	1500 existing public & private wells in agric. areas of U.S.	Approx. 50 + breakdown products.	ODW/OPP. State & county govts will probably participate.	Survey being designed	Report due late 1988. Focus is ag pesticides, but will include chlordane & NO3. Random sampling in high-med-low pest. usage & vulnerability areas
Evaluation of G-Water Quality in Relation to Land Use - USGS Toxic Waste-G-Water Contamination Program	To determine nature and extent of toxics contamination in various regions of the U.S., and to develop capability to predict g-w quality in terms of local hydrogeology, climate & land use.	14 regions throughout U.S.	Emphasis on trace metals and organics, including pesticides	USGS	Reconniassance completed. 2nd, intensive phase to begin for selected studies FY 86	Will take 4 years to complete. OPP funding reconnaissance and testing for Triazines, Nematocides, Alachlor, Carbofuran & Organophosphades in Kansas, Nebraska and California.
USGS Fed/State Cooperative Program	To study g-w quantity and quality in specific areas of concern. Some studies focus on agricultural chemicals.	Throughout USA	Variable, depending on concerns of state	USGS and State	Ongoing	USGS's major g-water monitoring program. $100 million per year, 50/50 Fed-State
EDB G-Water study in Seminole Co, GA.	Determine extent of contamination and source(s); support EPA's emergency suspension decision.	Seminole Co, Georgia	EDB	USGS, OPP & County Ag Extension Agent	Initial study complete. Follow-up in preparation.	

TABLE 4, continued

PROGRAM	PURPOSE	LOCATION	PESTICIDES MONITORED	RESPONSIBILITY	STATUS	REMARKS
G-Water study in northern Iowa	Determine ground-wate quality in four hydrogeological settings in agricultural regions of Iowa	Northern Iowa	many; focus is on herbicides	Univ of Iowa, Iowa Geological Survey, OPP	Funding recently approved	Expect to complete study & final report in late '87.
California Pesticide Movement to Ground Water study	Understand geographic distribution of g-water contamination by pesticides in 4 aquifers.	San Joaquin Valley & Riverside Co.	EDB, DBCP, Simazine, Carbofuran.	California Dept of Food & Agric/OPP	Complete	Provided key data for EDB emergency suspension in '83 and for recent Simazine regulatory actions.
DBCP assessment in Maui, Hawaii	Determine potential for drinking water contamination from DBCP to support regulatory decision.	Maui, Hawaii	DBCP	OPP & USGS	Completed in 1985	
Single chemical leaching studies	Registration of pesticides	Lab studies; field plots as needed	All registered pesticides	Pesticide registrants	Study requirements being increased	OPP developing guidelines to improve consistency & reliability of these studies. Will complete Fall '86.
Public Water Supply Program-SDWA Regulated Contaminant monitoring	Compliance with maximum contaminant levels (MCLs)	nationwide	Lindane Endrin Toxaphene Methoxychlor 2-4-D 2-4-5-T	ODW/ Public Water Systems		RMCLs have bee proposed for about a dozen pesticides, when they are issued as fina MCLs, monitoring will be required.

TABLE 4, continued

OGRAM	PURPOSE	LOCATION	PESTICIDES MONITORED	RESPON-SIBILITY	STATUS	REMARKS
uperfund onitoring	Hazardous substance clean-up & enforcement	nationwide	all haz. substances, incl. pesticides	OSWER/ states/ owners & operators	ongoing	Facility-spill oriented. Monitoring unlikely where clean-up is not feasible.
CRA Haz aste acilities onitoring	Detect & evaluate contamination; monitor compliance	nationwide - uppermost aquifer immediately beneath edge of waste.	???	OSWER/ states/ owners & operators	ongoing	
CRA Non- az Waste acilities onitoring	Compliance with facility guidelines (Subtitle D)	specified by state	In general, contaminants regulated under the SDWA	states/ owners & operators	ongoing	

E. Remaining Information Needs

While significant advances have been made in our understanding the behavior, extent, causes, and exposure to pesticides in ground water, uncertainty remains. We do not know how widespread the problem is nationwide. We have trouble determining where, how long, and how much particular pesticides have been used. We can locate only generally where soil and rock will permit movement of pesticides to ground water. We can make crude estimates, at best, about how long pesticides will persist underground and in what direction they will move.

Such uncertainties impair our ability to determine whether it is safe to use a particular pesticide in a specific place. Following is a discussion of the information needed to refine our basic understanding and clear up these uncertainties.

- Which pesticides have the potential to leach to ground water?

  The chemical characteristics that determine the probability a particular pesticide will leach are understood. EPA has identified more than a hundred potential leachers among the pesticides currently being used, and has collected additional environmental fate data on them to allow full evaluation of their ground-water contamination potential. Information about leaching potential is now required routinely for registration of all new chemicals and re-registration of all existing chemicals. With this information, EPA is now able to determine which chemicals have the potential to leach.

- What environmental conditions and farming practices enhance the potential for a pesticide to leach to ground water?

  These conditions are generally understood and are described under "Factors Influencing Leaching." Predictive models have been developed to determine the potential for a chemical to leach. The models are now being used to give general estimates of contamination potential over large areas. The models were not designed to accurately predict pesticide movement from individual field sites.

-- Model validation, in which models are tested and refined to predict leaching under a variety of field conditions, will enhance our ability to make more accurate predictions on a site-by-site basis. When the model validation work currently underway at Dougherty Plains is complete, EPA should have improved understanding of the factors which affect leaching and be able to make more accurate predictions of ground-water contamination.

-- Methods are needed for obtaining accurate, site-specific soils and hydrogeologic data to enter into leaching models. Inappropriate input data is the largest source of error in model predictions.

The effects of different application practices (rate, timing, method, irrigation and cultivation practices) on pesticide leaching to ground water have not been well understood. Since pesticide usage and application practices interact with environmental conditions to contaminate ground water, it is important to be able to evaluate them in the development of national strategies and individual farm plans. EPA's Integrated Environmental Management Division will complete an evaluation in 1986 of the influence of farming practices and environmental conditions on pesticide concentrations in ground water, surface water, and air. This study covers 18 pesticides, and looks at the influence of tillage (conservation) practices and hydrogeologic factors in three regions of the U.S. However, significant uncertainty will remain after this study is completed.

-- Further investigation is needed to reduce the uncertainty in these analyses and to consider a broader range of chemicals, hydrogeologic conditions, and application practices. Required "mechanistic" studies by pesticide munufacturers, as well as continued EPA research, would help provide this information.

o What conditions other than leaching from land application can result in ground water contamination?

A number of these conditions are known. They include pesticide spills at manufacturing/formulating and mixing/loading sites, backflushing from chemigation systems, disposal of pesticide products and containers in abandoned wells and dry wells, seepage into improperly sealed wells, and pesticide wastes leaking from landfills and dumps. However, the location and extent of these problems is not well known (see below).

- o Where has pesticide contamination occurred and where is it a potential threat?

While the first three questions seek better understanding of how pesticides reach ground water, this one seeks to answer the extent to which it has, or is likely to, occur. Of course, it is necessary to understand how contamination occurs in order to know where to look for it, so these questions are all interrelated. Exposures to pesticides in ground water are, by their very nature, localized problems. There may be numerous sites across the country where these exposures are occurring. However, the situation at each of these sites will be the result of a particular combination of local causative factors. National assessment of leaching potential must reflect these local factors.

-- A basic need is thus a national pesticides in ground water information system that will estimate contamination potential based on pesticide use, farming practices, location and use of ground water, and hydrogeologic factors that determine vulnerability to contamination. The National Survey of Pesticides in Ground Water, by conducting monitoring and correlating results with information on local conditions such as historical pesticide use, is designed to perform this assessment.

-- Up-to-date and accurate pesticide use data is needed in sufficient detail to pinpoint loadings in areas of concern. Historical pesticide usage information is essential for screening potential "hot spots" and for generating model inputs, but the data are usually not available.

-- Field data on pesticides in ground water is scarce. More actual monitoring is needed to help identify problem chemicals and affected areas.

-- Comprehensive monitoring of "point" sources of pesticide contamination (spills, leaks, etc.) is not feasible because the sources are typically small and detection is difficult. Because such sources may result in locally severe contamination, improved detection efforts are needed.

- How do pesticides move and persist once they have reached an aquifer?

  Understanding of the fate and transport of pesticides in ground water is limited, yet they are important considerations in determining the extent of a contamination plume and its expected duration. Unfortunately, ground water movement is difficult to predict in many types of aquifers and in any case requires substantial knowledge about the hydrogeologic conditions at the site of concern. Whether and how the pesticide breaks down in ground water is also an important consideration in estimating potential human exposures to the parent compound and its breakdown products, which may be more or less toxic.

  Increased understanding is needed in several areas:

  -- Pesticide behavior in the saturated zone, including pesticide degradation in aerobic and anaerobic ground-water environments.

  -- Ground-water flow mapping and other hydrogeologic data in areas where pesticide contamination is a concern.

  -- Estimates of pesticide accumulation in ground water, including models to predict accumulations from multi-year applications.

  -- Interactive or synergistic effects on ground water of applying different chemicals.

- Who uses, and how frequently, drinking water that is found or predicted to be contaminated?

  Exposure to pesticides in drinking water is poorly understood. There has been very little monitoring for these chemicals. Private wells are especially threatened because they are frequently shallow and close to where crops are grown, but they are seldom if ever tested. The planned National Survey of Pesticides in Drinking Water Wells is a statistically designed sampling program for pesticides in public and private wells. The results should enable us to draw conclusions about the extent of well contamination nationwide and the probability of contamination in specific locales.

- -- Exposure estimates would also be improved by obtaining more accurate well density and location information in areas with a high potential for contamination.
- -- More routine monitoring of public and private wells for pesticides used in their vicinities would also improve the overall information base.
- -- Because testing is very expensive, improved multi-residue analytic techniques are also needed.

Improvements in the Quality and Accessiblity of Pesticides in Ground Water Data is a Basic Need. Groundwater quality efforts are generally plaqued with data quality and data management problems. Data on pesticides in ground water is no exception.

- -- There is a basic need to improve communications and data management among the various Federal, State, and local agencies concerned with pesticides in ground water. Considerable data exists that are unknown to ground-water managers who could make good use of it. A national system for coordinating data collection, storage, and access is essential.
- -- Ground-water monitoring data is of uncertain quality. Monitoring and testing are conducted mostly by State and local agencies without centralized control. Development of testing protocols and performance of integrity audits would help assure data reliability.

II. Assessing Health Risks From Pesticides

A. The Need for Health Significance Information

Understanding the health effects of pesticides in drinking water is essential to developing an approach for addressing the problem of pesticides in ground water. Just as modeling and monitoring are vital tools for assessing the environmental presence and significance of pesticides in ground water, a variety of health numbers and health assessment activities provide the tools needed by EPA to evaluate the health significance of pesticides in ground water.

Health significance findings are vital to EPA in supporting regulatory decisions and response actions for pesticides occurring in ground water. Determining the health significance of pesticides is also known as risk assessment, and risk assessment along with several other important considerations forms the basis for risk management decisions to initiate regulatory and/or response actions as appropriate. EPA's regulatory and response actions can be effective and responsive only if they are based on sound data and assessments of the nature and degree of the risks posed.

EPA uses a somewhat standardized procedure for assessing health/environmental risks. However, even though individual Agency program offices all follow the same basic risk assessment process (which will be described later in this section), they often arrive at different characterizations of the nature and degree of the risks posed, and make different decisions concerning management of pesticide contaminants in ground water. These differences occur almost invariably because different statutory mandates, priorities, and management considerations are brought to bear on the same pesticide chemicals and groundwater contamination problems. A considerable effort is being made within EPA to achieve a unified position on the health significance of pesticide residues in ground water so that risk management decisions may be consistent, if not identical, across program lines.

EPA is starting from a relatively advantageous position in addressing the health significance of pesticides in ground water. More is known about the toxicity of pesticides than about many other chemicals, since many pesticides have undergone extensive toxicity testing for the purpose of establishing tolerances for residues in food. Where toxicity data on pesticides are lacking or inadequate, they are being required of pesticide registrants for product re-registration and tolerence reassessment.

Estimates of human populations actually or potentially exposed to pesticides through ground water used as drinking water are less certain, though the Agency is actively working to increase the information base on this side of the hazard assessment equation. In the absence of actual exposure data, the different EPA programs are taking different approaches and making different assumptions about exposure. These different assumptions result in the variety of "health numbers" or safety/acceptable risk levels generated and used throughout the Agency.

This section describes the risk assessment process used by EPA to assess the health significance of pesticides in ground water, and discusses the different health risk numbers and issues that have resulted as Agency program offices have brought several statutes, sets of data, and assumptions to bear on the matter of risks posed by pesticides that may be found in ground water.

B. Health Risk Assessment for Pesticides in Ground Water

Before an Agency manager may initiate regulatory or response action on a pesticide posing an unreasonable risk through its actual or anticipated presence in ground water, the nature and extent of the risk must be known and characterized. That is, pertinent data and information about the pesticide and its hazards must be compiled, analyzed, and evaluated. The resulting risk assessment will be considered along with other economic, political, and social factors by the decision maker in arriving at a risk management conclusion.

Risk assessment incorporates both qualitative and quantitative assessments: the qualitative assessment of whether the risk will occur and the quantitative assessment of the magnitude of the risk. The need for risk assessment is usually prompted by the results of research or human experience which suggests that adverse effects may be caused by the exposure. Assessing the risks of chronic chemical exposure is complex because the association between cause and effect is difficult to identify, particularly when the risk is low or the number of people is small (as is often the case with pesticide contamination of particular wells). Risk assessment often involves making inferences from limited scientific data on the basis of what we currently know about the underlying biological processes.

EPA's method of risk assessment for potential ground-water contaminants and other chemicals is based on a process first characterized by the National Academy of Sciences. This risk assessment process contains four components:

1) Hazard identification - The determination of whether a particular chemical is causally linked to particular health effects. To make this determination, Agency scientists review and analyze toxicity data; weigh the evidence that a substance causes various toxic effects; and evaluate whether toxic effects in one setting will occur in other settings. The toxicity data considered include human studies (case reports, clinical studies, and epidemiologic studies), animal studies (general and specialized toxicity studies), and short-term tests often carried out on microorganisms.

2) Dose-response evaluation - The determination of the relation between the magnitude of exposure and the probability of occurrence or severity of the health effects. Dose-response evaluation is performed to measure the adverse effect that is likely to occur at the lowest exposure level. It often involves extrapolation from high to low dose (in animals), extrapolation from animals to humans, and occasionally extrapolation of the dose-response relationship from one exposure route to another.

3) Human exposure evaluation - The determination of the extent of human exposure before or after application of regulatory controls. Three routes of human exposure are considered: ingestion, inhalation, and skin contact. Agency scientists determine in which media the substance may be present (water, food, air, soil), and how people may be exposed (drinking, eating, inhalation, skin contact). They then identify population groups who may be exposed. Finally, they determine, by actual measurement or by environmental fate modeling, the concentration of the substance in these media and the amount of human intake through exposure to the media (i.e., the magnitude, duration, and timing of the exposure). Among the many uncertainties associated with each of these steps is that which may result from comparisons of modeling and actual monitoring data.

4) Risk characterization - The description of the nature and often the magnitude of human risk, including attendant uncertainty. Risk characterization integrates the data collected in the first three steps to characterize the potential risk to humans.

Statistical and biological uncertainties in estimating the extent of the health effects are always described.

Certain issues are associated with each step of the risk assessment process, including:

1) Hazard identification issues:

- Use of animal data in evaluating risks to humans
- Negative epidemiological studies

2) Dose-response evaluation issues:

- Extrapolating from high dose to low dose
- Extrapolating from animals to humans
- Extrapolating from one exposure route to another

3) Human exposure evaluation issue:

- Modeling vs. ambient monitoring vs. personal monitoring

4) Risk characterization issue:

- Qualitative or quantitative

Although various uncertainties and issues are involved at each step of the risk assessment process, it does provide the Agency with a clear, consistent framework for estimating the health significance of pesticides in ground water and other media. This process is sufficiently flexible to permit consideration of different types of data and formulation of different evaluations and conclusions by different program offices even in assessing risks associated with the same chemical. This flexibility is necessary to ensure that the process is useful to all programs and anyone else who is interested in conducting risk assessments. However, it is important to recognize that use of the same basic process can produce different evaluations, even for the same pesticide, depending upon the data and assumptions included.

EPA carries out several risk assessment activities that are pertinent to pesticides in ground water, and in so doing generates a variety of health significance numbers. The major types of these health numbers and their uses are described in this section.

Since several program offices throughout EPA prepare risk assessments, over the years, multiple and sometimes conflicting health numbers have been developed for the same chemical by different Agency offices. EPA is working to resolve this problem. A committee has been established to resolve conflicting health numbers within the Agency and to ensure that for all future chemical-specific assessments, one Agencywide number is developed and used.

C. Reference Dose as Benchmark

The Reference Dose (formerly known as Acceptable Daily Intake, or ADI) is the amount of a pesticide or other chemical that may be taken into the body daily with practical certainty that injury will not result, even after a lifetime of exposure. To assess the significance of pesticides in ground water, EPA has established the Reference Doses for several pesticides which can be used as benchmarks for determining potential hazard.

The Reference Dose is based on a rigorous evaluation of animal studies and, when available, human data. Although in most cases the Reference Dose is based on one or more chronic feeding studies, other studies such as multigeneration reproduction studies may also be used to set a Reference Dose.

The Reference Dose is derived by applying an uncertainty or safety factor to the results of animal toxicity studies. More specifically, animal studies are evaluated and the lowest dose eliciting any type of toxicological response is identified. This dose is known as the lowest-observed-adverse-effect level (LOAEL). The dose immediately below the LOAEL in the same study must, by definition, elicit no toxicologic response and therefore is called the no-observed-adverse-effect level (NOAEL). The NOAEL and thus the Reference Doses are expressed as mg/kg of body weight per day. The NOAEL from a particular test is converted into a human Reference Dose by using an appropriate uncertainty or safety factor, to allow for the uncertainties in extrapolation from animals to humans and for the differences in sensitivities which exist within the human population. Examples of uncertainty factors used by EPA for various types of effects and durations of testing are listed in the table below.

Standard Uncertainty Factors for Toxicological Effects

Note: An uncertainty factor of 10 is included for each condition

Condition	Uncertainty Factor
o Species extrapolation required	10
o Short term or subchronic data used for estimating chronic levels	10
o Data on normal individuals used to estimate levels for sensitive subgroupings	10

Reference Doses generally are already available for those pesticides used on raw agricultural commodities. In addition, for those pesticides which are determined to be oncogenic in laboratory animals or in epidemiological studies, EPA extrapolates from various doses to arrive at doses corresponding to various levels of increased cancer risk. Adjustments for species differences and for partial lifetime exposure are made as required using procedures described in EPA's Guidelines for Carcinogenic Risk Assessment. These risks are presented in tabular form to help the appropriate regulatory program determine the risk level which can be tolerated after consideration of scientific and other factors.

There are several ways in which EPA can use the Reference Dose and can factor in human exposure to arrive at risk assessments for pesticides in ground water. Different program offices within EPA use the Reference Dose in different ways, each considering multi-media exposure to pesticides in a different fashion. One approach is to factor all sources of exposure (air, food, and water) into the Reference Dose and, if data are not available on the relative contribution of the contaminant, develop an arbitrary apportionment. An alternative approach is not to apportion the Reference Dose according to sources of exposure, but instead to consider pesticide uses on a case-by-case basis, combining dietary and drinking water exposure as appropriate. The activities of the Office of Drinking Water (ODW) and Office of Pesticide Programs (OPP) exemplify these two approaches.

- ODW determines Recommended Maximum Contaminant Levels (RMCLs)*/ by apportioning the Reference Dose according to the contribution of the chemical through drinking water, food, and air. If data are available, the RMCL is determined by subtracting from the Reference Dose the known contribution of the contaminant in food (using food tolerances and other data), and air. If data are not available, ODW uses an estimation of the percentage of exposure attributable to an exposure route. For organic chemicals, the percentage of drinking water exposure used in the absence of known exposures is 20 percent, and for inorganic chemicals a 10 percent contribution is used, since sources other than drinking water are more likely carriers for inorganics.

- OPP, in setting pesticide tolerances (that is, residues that can remain on crops treated by pesticides),**/ compares the dietary exposure of the pesticide to the Reference Dose. OPP has developed and is starting to use a "Tolerance Assessment System" (TAS) which calculates distributions of exposure, crop group distributions, and exposures to a pesticide on the day that a commodity is eaten, as well as averaged exposures over a period of time. This system may be used to estimate pesticide exposure on a fairly detailed level and has the capability of estimating consumption of a pesticide through drinking water as well as food. Thus, the estimated exposure that is compared to the Reference Dose is now as accurate as possible.

  To assess exposure for new pesticides, OPP estimates dietary exposure and characterizes as accurately as possible the potential for ground-water contamination. OPP proposes that for those pesticides that have a high leaching potential, ODW will be requested to establish a health advisory level and this additional exposure is considered as a "worst case" drinking water exposure in the overall exposure estimate. To assess or reassess exposure for existing, registered pesticides (which have established tolerances, an OPP-established

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*/ See discussion of RMCLs which follows.

**/ See discussion of Tolerances for Pesticide Residues which follows.

Reference Dose, an ODW-established health advisory level in drinking water, and for which drinking water exposure can be quantified), OPP will consider adding the drinking water contribution to the dietary contribution resulting from established tolerances, and characterize as accurately as possible the population for which this exposure and its associated risk are relevant (i.e., the population likely to drink contaminated water). If the population cannot be characterized, the uncertainties in the exposure assessment are clearly expressed. A separate exposure assessment is made for the general population.

These varying approaches result in different "health numbers" being used within the Agency even though the starting point -- the Reference Dose -- is identical. Efforts are ongoing to integrate the two approaches described above so that consistent risk assessments and health numbers are generated for pesticides that may contaminate ground water. Options for addressing this issue are also being developed as part of the Agricultural Chemicals in Ground-Water Strategy.

D. Program-Specific Risk Numbers and Assessments

Office of Drinking Water

Under the Safe Drinking Water Act, EPA is required to establish drinking water regulations to assure the safety of the water served by public water systems. For contaminants which the Administrator judges may have an adverse effect on the health of persons, EPA specifies the maximum contaminant level (MCL) that can be allowed in public water supplies, or for contaminants that cannot be readily detected, treatment techniques that must be employed to remove them. EPA is also required to first specify Recommended Maximium Contaminant Levels (RMCLs), which are non-enforceable health goals. The MCLs, which take into account the feasibility and cost of removing the contaminant, must then be set as close to the RMCL as feasible and are enforceable. Non-regulatory health advisories are developed by EPA to provide information following inadvertant contamination of drinking water. (See discussion of the Safe Drinking Water Act in Chapter II for a more detailed discussion.)

(1) Recommended Maximum Contaminants Level (RMCLs)

RMCLs are set based upon a three-category approach in which chemicals are classified based upon the strength of evidence of their carcinogenicity as follows:

- Category I - Strong evidence of carcinogenicity.
- Category II - Equivocal evidence of carcinogenicity.
- Category III - Inadequate or no evidence of carcinogenicity in animals.

Category I includes those chemicals which, in the judgment of EPA, have sufficient human or animal evidence of carcinogenicity to warrant their regulation as known or probable human carcinogens. RMCLs for these compounds are set at zero. These compounds are potential human carcinogens and they have not been demonstrated to exhibit a threshold; thus it is assumed for the purpose of regulation that any exposure could contribute some finite level of risk.

Category II includes those chemicals for which some limited but insufficient evidence of carcinogenicity exists from animal data. These are not regulated as known or probable human carcinogens. However, RMCLs reflect the fact that some experimental evidence of carcinogenicity in animals has been reported.

EPA uses one of two options for setting the RMCLs for these types of chemicals. The first option consists of setting the RMCL based upon non-carcinogenic endpoints (the Reference Dose, with an additional uncertainty factor) if adequate data exist. The second option consists of setting the RMCL based upon an estimate of increased lifetime risk. EPA uses the first option if valid non-carcinogenic data are available upon which to base a Reference Dose. If valid non-carcinogenic data are not available and risk levels have been calculated, then risk calculations are used.

EPA believes that both of these approaches reflect the primary consideration concerning Category II chemicals: RMCLS should be less conservative than those for Category I chemicals and more conservative than those for Category III chemicals.

Category III includes those substances with inadequate or no evidence of carcinogenicity. RMCLs are calculated based upon chronic toxicity data using Reference Doses.

The percentage of exposure from drinking water often used in determining the RMCLs is a 20 percent contribution for organic chemicals and a 10 percent contribution for inorganic chemicals. The National Interim Primary Drinking Water Regulations used 20 percent as the drinking water exposure factor for pesticides.

This exposure factor is judgmental and is adjusted when mitigating information exists; however, use of a 20 percent contribution is considered to be reasonably conservative and protective.

(2) Maximum Contaminant Levels (MCLs)

The general approach to setting MCLs is an evaluation of the availability and performance of technologies, and an assessment of the costs of the application of technologies to achieve various levels (that would be as close to the previously set RMCL as possible or equal to the RMCL). MCLs are determined based upon an analysis of technologies, costs, and other factors relative to feasibility.

The RMCLs and MCLs are published in the Federal Register and go through the full rulemaking process, including public review and comment.

(3) Health Advisories (HAs)

The Office of Drinking Water's non-regulatory health advisory program provides information on health effects, analytical methodology, and treatment technology following inadvertent contamination of drinking water. Health advisories also describe concentrations of contaminants in drinking water at which adverse effects would not be anticipated to occur. A margin of safety is included to protect sensitive members of the population.

Health advisories are not legally enforceable Federal standards. They are subject to change as new and better information becomes available. The advisories are offered as technical guidance to assist Federal, State, and local officials responsible for protection of the public health.

The health advisory numbers are developed from data describing non-carcinogenic end-points of toxicity, using the Reference Dose procedure described earlier for RMCL development. Relative source distribution (exposure from drinking water, food, and air) is also factored into the health advisories.

The health advisories are non-regulatory numbers and do not go through the rulemaking process. Currently, an informal mechanism of dissemination exists, by which each Regional Office receives a set of health advisories and distributes them to States and other interested parties upon request. In addition, health advisories are available through the National Technical Information Service (NTIS). The Office of Drinking Water is currently developing a new strategy for dissemination of health advisories to better ensure that the information is available to all interested parties.

Office of Emergency and Remedial Response

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) establishes a national program for responding to releases of hazardous substances into the environment. In determining the type and level of cleanup to undertake, the Agency must comply with all applicable or relevant and appropriate Federal public health or environmental laws, including drinking water standards. The Agency must also consider other Federal criteria, advisories, guidance, and State standards such as ODW's health advisories. During this process, EPA gives primary consideration to the selection of those response actions that are effective in preventing or, where prevention is not practicable, minimizing the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health, welfare, or the environment.

As a general rule, the Agency's policy is to attain or exceed the requirements of applicable or relevant and appropriate Federal public health or environmental laws unless one of the specifically enumerated situations is present. Where such a situation is present and a requirement is not followed, the Agency must document and explain the reasons in the decision documents. Other Federal criteria, advisories, guidances, and State standards also will be considered and may be used in developing remedial alternatives, with adjustments for site-specific circumstances. If EPA does not use, or uses and adjusts, any pertinent standards in this category, EPA will fully document the reasons why in the decision documents.

(1) Health Effects Assessments (HEAs)

Among the other Federal criteria, advisories, guidances, and State standards considered, Health Effects Assessment (HEA) values are given primary consideration. HEA values are developed by the Office of Research and Development (ORD) for the Office of Emergency and Remedial Response (OERR). They are subject to change as new and better information becomes available. For those hazardous substances for which HEA values have not been developed, other public health and environmental values should be considered.

The HEA values represent two types of route-specific exposure levels that have been estimated for systemic toxicants. The first, the maximum dose tolerated for subchronic exposure, is an estimate of an exposure level which would not be expected to cause adverse effects when exposure occurs during a limited time interval, i.e., for an interval which does not constitute a significant portion of the lifespan. This type of exposure estimate has not been extensively used, or rigorously defined, as previous risk assessment efforts have been primarily directed toward exposures from toxicants in ambient air or water where lifetime exposure is assumed.

The maximum dose tolerated for chronic exposure is similar in concept to the Reference Dose. It is an estimate of an exposure level which would not be expected to cause adverse effects, when exposure occurs for a significant portion of the lifespan. This estimate is route-specific and estimates acceptable exposure for a given route with the implicit assumption that exposure via other routes is insignificant.

The HEA values are non-regulatory numbers and do not go through the rulemaking process. Currently, an informal mechanism of dissemination exists, in which each Regional Office receives a set of HEAs and the HEAs are distributed to States and other interested parties upon request. In the future, HEAs will be available through both the Center for Environmental Research Information (CERI) of ORD, and the National Technical Information Service (NTIS).

Office of Pesticide Programs

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) authorizes a pre-market licensing or registration process for all pesticides marketed and used in the United States. Registration decisions are based on the evaluation of test data submitted by registrants in accordance with Part 158 of Title 40 of the Code of Federal Regulations (U.S. EPA, 1982).

Toxicity data requirements for food use pesticides typically include the following studies: a battery of acute tests, two chronic studies (including one in a non-rodent), two oncogenicity studies (in two species), two teratology tests (in two species), a multigeneration reproduction study, and other tests, such as a delayed neurotoxicity test, depending on the chemical structure. Environmental fate studies are also required for all terrestrial outdoor use pesticides. These are the studies upon which OPP bases its determination of a pesticide's leaching potential.

Under section 3(c)(2)(B) of FIFRA, EPA has the authority to "call in" from registrants any needed data on the health or environmental effects of their registered pesticides.

In addition, OPP has authority under the Federal Food, Drug, and Cosmetic Act (FFDCA) to set tolerances, or legal limits, for pesticide residues in raw agricultural commodities, processed foods, and animal feeds. No pesticide may be registered by EPA for a food or feed use until a tolerance has been established or an exemption from the tolerance requirement has been issued.

(1) Tolerances for Pesticide Residues

Decisions on tolerances for pesticide residues remaining in or on treated food or feed products are based on reviews of data submitted by petitioners, who are often the applicants for registration. Estimated exposures are compared to the Reference Dose which is established based on the evaluation of the entire toxicity data base. For pesticides which are determined to be oncogenic in laboratory animals, EPA carries out a low dose risk extrapolation to arrive at levels of risk. Exposure estimates in the past have usually been carried out by assuming residues of pesticides at the legal tolerance level and assuming consumption at the level of standard food factors. This estimate of exposure is referred to as the Theoretical Maximum Residue Contribution (TMRC).

The TMRC assumes that 100% of each crop for which the pesticide is registered is actually treated and that all crops contain residues at the tolerance level. When the TMRC exceeds the Reference Dose, the Office of Pesticide Programs attempts to more realistically estimate exposure to determine the actual extent of risk. If essential data are not available, registrants are required to submit the data under FIFRA section 3(c)(2)(B). If after this evaluation the TMRC is still exceeded, OPP can reduce or revoke tolerances for various commodities.

Over the course of the last few years, the Office of Pesticide Programs has developed the capability to be more precise and detailed in its description of exposure. The new "tolerance assessment system" (TAS), developed by the Office of Pesticide Programs allows the calculation of the mean dietary exposure for the U.S. population and for 22 subgroups. It will also calculate distributions of exposure, individual commodity contributions, crop group distributions, exposure to a pesticide on the days that a commodity is eaten (single serving sizes), as well as an averaged exposure over a period of time. This new computerized system has the capability of estimating consumption of a pesticide in drinking water as well as through food.

Traditionally, exposure to pesticides in drinking water has not been combined routinely with dietary exposure but has been compared separately to the Reference Dose. However, the estimated exposure that is compared to the Reference Dose can now be extremely accurate, given the limitations specific to each compound. Consistent with this approach is the combining of dietary and drinking water exposure as appropriate. In those cases where drinking water exposure can be quantified, the Office of Pesticide Programs proposes to assess drinking water and dietary exposure to pesticides by combining the drinking water contribution with that resulting from dietary sources, and characterizing as accurately as possible the population for which this exposure and its associated risk are relevant. OPP will also estimate the exposure and percentage of Reference Dose utilized for the general population (and the population subgroups that are a part of the new Tolerance Assessment System) for dietary exposure that does not include drinking water.

Tolerances established by EPA are regulations and are published first as proposed and later as final rules in the Federal Register. Ultimately, they are codified in Parts 21 and 40 of the Code of Federal Regulations. The food and feed tolerance regulations promulgated by EPA are enforced by the U.S. Department of Agriculture (for meat, poultry, and eggs) and the Food and Drug Administration (for other food and feed commodities). Both domestic and imported food and feed moving through the channels of U.S. commerce must comply with the pesticide tolerance regulations established by EPA. Commodities found to be in violation of tolerance regulations are subject to seizure and destruction.

E. Current Efforts to Improve Health Significance Knowledge

Health risk assessment is a relatively new procedure, and it is often described as both art and science because of the inherent difficulties involved in determining potential human health risks based on toxicity data that is often incomplete or inconclusive. Despite these difficulties, health risk assessment is a fundamental tool used by all EPA programs to characterize the potential for harm to human health by chemical substances in the environment. These assessments form a key part of the basis upon which policy makers determine whether, and to what extent, measures to reduce risks are warranted. While decisions regarding risk management for the same chemical may vary because each EPA program has unique statutory requirements and addresses a somewhat different aspect of potential human exposure, the Agency has in recent years initiated several efforts to assure that risk assessments themselves are consistent across the Agency.

The Agency is developing guidelines to be used by all EPA programs in evaluating toxicity studies for a variety of health effects. Because of the continuing evolution in risk assessment methodology, a standing Risk Assessment Forum has been established that will convene technical panels as needed to revise the guidelines and help resolve new or unusual problems not addressed by the guidelines. A committee of senior scientists has also been set up to achieve consensus on conflicting "Reference Doses" (formerly known as Acceptable Daily Intake, or ADI) which now exist and to assure use of one Reference Dose for each chemical throughout the Agency. The Agency anticipates establishing a comparable committee to assure consistency in the way the Agency expresses cancer risks.

Coordination between the Office of Pesticide Programs and the Office of Drinking Water is particularly important, for each has a need to determine risks presented by pesticides in the diet and in drinking water. The two offices are now implementing a Memorandum of Understanding outlining how they will share and use information in developing health guidances for pesticides. The offices plan to develop jointly, on an accelerated basis, more than 50 health guidances on those pesticides that will be included in the National Survey of Pesticides in Drinking Water Wells.

CONCLUSION

The potential threat that pesticides pose to ground water quality -- and thus to an important source of drinking water for many Americans -- has only recently become widely recognized. The problem raises complex technical, institutional, and policy challenges for the many agencies at all levels of government involved in ground-water protection, public health, and agricultural production. In this report, we have tried to present the context in which public policy regarding pesticides in ground water will develop.

Steady advances have been made in the last decade, but many scientific and technical uncertainties remain about the causes of contamination and under what conditions it is likely to occur. Relatively little is known about how to reduce the risk of leaching; the research conducted thus far points to a few promising directions but has yet to provide conclusive results. We understand the potential for contamination from leaks, spills, and disposal of pesticides -- as well as some techniques for controlling such sources -- but we do not yet know their relative contribution to the overall contamination problem.

The health risks presented by trace levels of pesticides in drinking water can be estimated, but there are inherent uncertainties built into risk assessment methods as well as a continuing need for adjustments as new toxicity data becomes available. Increasing monitoring data and mathematical models are now available, however, we remain limited in our ability to predict where and at what levels contamination is occurring or will occur, and lack information on well locations in regard to pesticide usage. Thus, it is difficult to estimate potential human exposures to contaminated ground water.

There are many efforts now underway to improve our prediction capabilities and exposure calculations. The National Survey of Pesticides in Drinking Water Wells, in particular, will provide valuable information. Other monitoring and research efforts being undertaken by a variety of agencies and organizations will add to the information base. Clearly, as more becomes known, we will be in a stronger position to determine what actions to take both in preventing contamination and in responding to contamination incidents.

From an institutional standpoint, many laws and programs are already in place to address pesticides in ground water. The challenge will be to use the existing laws more creatively and effectively, and to establish workable arrangements between the many interested Federal, State, and local agencies toward a common goal of protecting ground (and surface) water quality while sustaining a viable agriculture. Adjustments in traditional relationships between EPA and the States on pesticide matters may be needed so that local variability in hydrogeology, agricultural practices, and pesticide usage can be accommodated both in determining the risks pesticides pose to ground water and in designing and implementing appropriate controls.

Especially within the last two years, there has been an increasing level of interest and commitment to solving the problem of pesticides in ground water at all levels of government. EPA is now developing a national strategy on Agricultural Chemicals in Ground Water. A majority of States have identified the problem as a high priority concern, and many are developing and implementing monitoring programs and control strategies as part of their State ground-water protection efforts.

Because of the many complex factors involved, it will be years before the problem of pesticides in ground water will be fully understood, solutions implemented, and results evidenced. However, considerable progress is being made -- by EPA as well as by other Federal, State, and local agencies, researchers, the pesticide industry, pesticide users, and the interested public -- toward increasing our understanding of the problem and finding mutually acceptable solutions. In preparing this report, a conclusion became apparent: We need to encourage and take advantage of the best, most innovative thinking about preventive and remedial approaches and to open new avenues of cooperation and coordination among all the parties involved to achieve the greatest overall protection of ground water for current and future generations. EPA invites all interested members of our society to join us in meeting the challenges presented by pesticides in ground water.

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